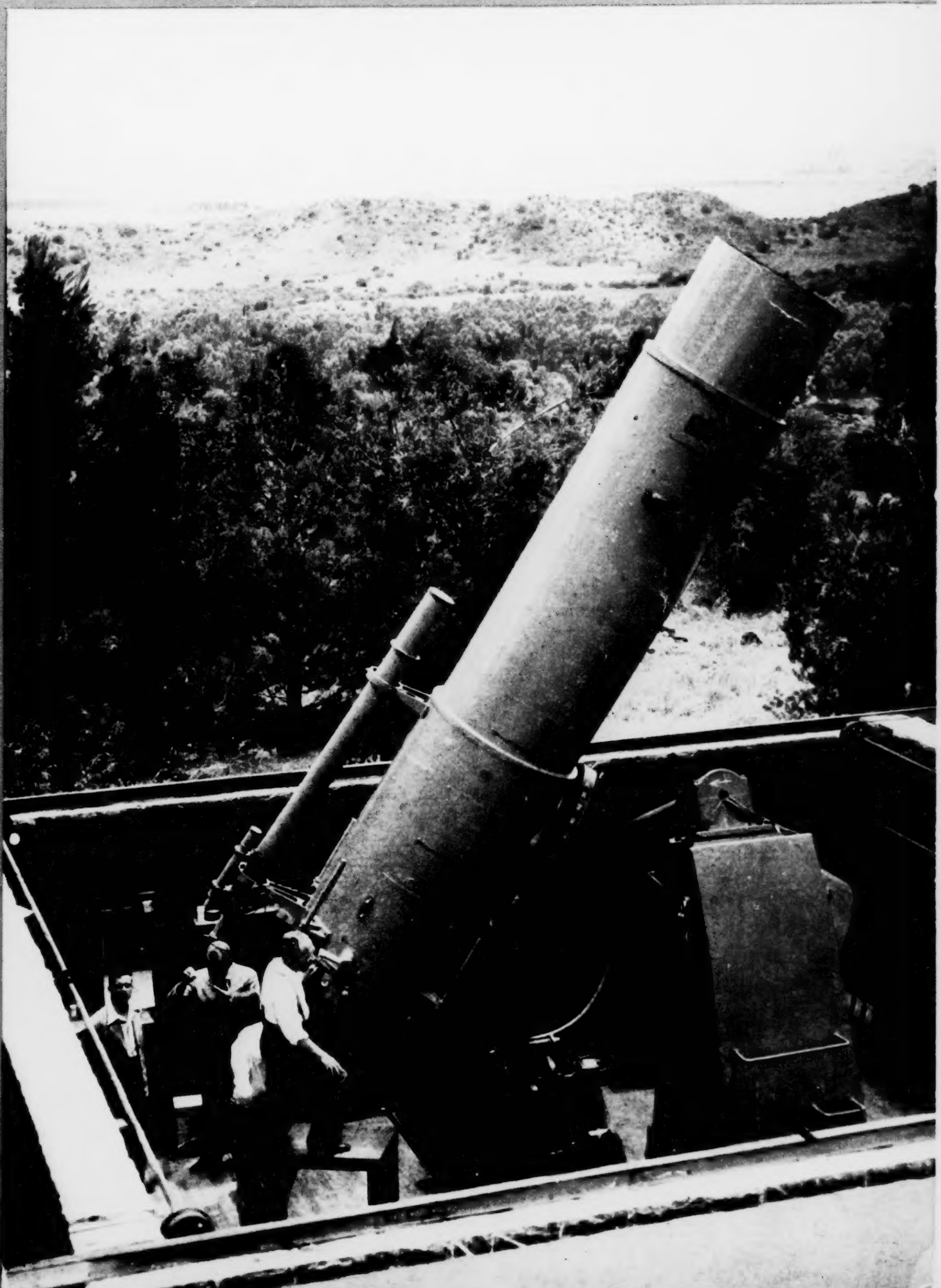
Sky and TELESCOPE



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The ADH telescope

L. J. COMRIE

THE WORLD of computational astronomy lost a pioneer with the death of L. J. Comrie on December 11, 1950. Dr. Comrie made his lifework of what was originally a hobby of collecting and editing mathematical tables, and figuring short cuts and new methods in computing. He was born in New Zealand in 1893, and attended the Auckland University College as the Sir George Grey scholar and senior university student. He saw active service with the New Zealand troops in World War I. On June 9, 1918, while he was on board a troopship off the coast of Egypt, he observed a strange bright object in the evening sky — Nova Aquilae 1918. Unfortunately for him, it had been discovered the previous evening by a number of observers who had clear skies in other parts of the world, when he had heavy clouds over the Mediterranean.

After the war, he went to England and continued his studies in mathematics and astronomy at Cambridge University, where he was Isaac Newton student. He came to the United States in 1922 as assistant professor of mathematics and astronomy at Swarthmore College, and in 1924 was made assistant professor of astronomy at Northwestern University. At Swarthmore, he initiated the first course in practical computing ever to be given with credit toward a college degree.

In 1926 Dr. Comrie returned to England as deputy superintendent of H. M. Nautical Almanac Office. He later became superintendent, and remained there until 1936. He introduced modern machines into the almanac office and completely reorganized the computing methods. One of his favorite studies was the legibility of type faces. All of his publications were printed in most readable form. National almanac offices all over the world have adopted many of his innovations. He left the British Almanac Office in 1936 to devote his time and energy to the Scientific Computing Service, Ltd., one of the first organizations in the world set up to do scientific computing of all kinds. He emphasized the desirability of making use of standard machines which were available to anyone, and developed the use of the Brunsvega and Marchant twin machines. He was also one of the first users of punched card machines for astronomical purposes.

The day World War II broke out, a representative of the British government called on Dr. Comrie and asked him if he could produce some desperately needed tables within a month. The tables were computed and delivered within two weeks. Dr. Comrie remained in London throughout the war, and continued to do outstanding work for the allied governments.

His library contains one of the finest collections of mathematical tables, and his lists of errors found in them is very complete. He recognized the strong need for better tables of all kinds, and devoted much time to computing, editing, and publishing many different ones. Among his best known publications are: the third edition of Barlow's Tables, 1930; Standard 4-Figure Mathematical Tables, 1931; 4-Figure Tables with Argument in Time, 1931; Hughes' Tables for Sea and Air Navigation, 1938; fourth edition of Barlow, 1941; Chambers' 4-Figure Mathematical Tables, 1947; and Chambers' 6-Figure Mathematical Tables, 1948. In addition, he wrote more than 100 papers on astronomical subjects, calculating machines, and mathematical tables.

L. J. Comrie (1893-1950)

In March, 1950, Dr. Comrie's fine work was recognized when he was elected a fellow of the Royal Society, with the following citation: "Distinguished for his mechanization of scientific calculation with the aid of commercial calculating machines and in particular for his improvements of finite difference methods by the application of multi-register machines. Also for his contributions to the art of constructing and presenting mathematical tables."

MARGARET W. MAYALL
Harvard College Observatory

SKY AND TELESCOPE

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The IBM Selective Sequence Electronic Calculator, located in New York City, combines electronic speed with a vast memory capacity. Devices for reading data and instructions into the machine and for recording results are shown in the foreground. Vacuum tubes on the right wall are part of the arithmetic, memory, and control units. This machine carried out over 12 million arithmetical operations in computing the orbits of the five outer planets. The results, being published as Volume XII of the "Astronomical Papers of the American Ephemeris," will comprise less than one per cent of the data used in the calculations. International Business Machines photograph.

The Motions of the Five Outer Planets

By G. M. Clemence, *U. S. Naval Observatory*, and Dirk Brouwer, *Yale University Observatory*

THE accurate measurement of the motions of the planets and the representation of these motions by a rigorous theory have played a basic role in the development of physical science, as well as in practical problems such as those of navigation. As the wealth of observational data accumulates over the years, the problem of adequately representing it by a consistent theory has become ever more difficult. The recent advent of the electronic calculator has at last made it feasible to perform the theoretical analysis with accuracy far greater than that of the accumulated observations. The project here described involved many millions of arithmetic operations, and the discussion of many thousands of observations has produced results of a new order of accuracy.

Jupiter and Saturn must have been among the earliest objects of intellectual curiosity. Before recorded history it was undoubtedly noticed that Jupiter appeared in the evening sky a month later each year, requiring 12 years for a complete circuit of the heavens, and that Saturn moved among the stars at less than half of Jupiter's speed. During the few centuries immediately preceding the Christian era, the Babylonian astronomers represented the observed motions by empirical arithmetical formulae; and somewhat later the Greeks represented them by means of hypothetical geometric systems of motions in space.

The Greek theories of the planetary motions culminated in the system constructed by Ptolemy, some 1,800 years ago. In this system, the motion of each planet is represented by superimposing one or more small circular motions in space upon a motion in a large circular orbit around the earth. The small circular motions account for the periodically varying speed with which the planet appears to move among the stars.

Ptolemy's system remained the accepted standard theory among astronomers for 14 centuries, and some of its features were retained by Copernicus when in the 16th century he proposed the theory that the planets move around the sun instead of around the earth. Meanwhile, observations of the planets had become precise enough to show that their motions were not accurately represented by these theories. In the early 17th century, Kepler found the planetary orbits around the sun to be ellipses; and he then developed laws for the elliptic motions from which formulae and tables for computing the positions of the planets were prepared and published in 1627. However, Jupiter and Saturn departed from Kepler's theory also; and it was not until after Newton had formulated the theory of universal gravitation that a satisfactory explanation for the divergencies was advanced.

This theory (which Newton arrived at in 1665 or 1666, although he did not announce it until 1686) postulates that every particle of matter in the universe attracts every other particle with a force along the line joining them, proportional to the product of their masses and inversely proportional to the square of the distance between them. Were a planet acted upon by only the gravitational attraction of the sun, the orbit would be an exact ellipse; the observed departures from elliptic motion may be attributed to the disturbing effects of the other planets. Assuming the correctness of this simple law, it becomes theoretically possible to solve what may be called the fundamental problem of celestial mechanics: Given the positions and directions of motion of several bodies (say Jupiter, Saturn, and the sun), together with their speeds and masses at a particular time, required to find their positions at any other time;

but the simple statement of the problem gives no idea of the formidable character of its solution. Ever since Newton's time the most eminent mathematical astronomers have devoted their lives to devising practical methods for solving it, and in applying these methods to the actual planets. The difficulty is illustrated by the lapse of more than a century after the publication of Newton's theory before a mathematical representation of the motions of Jupiter and Saturn was obtained that came reasonably close to meeting the requirements of that time.

Two methods have proved to be successful in practice. In one, called the method of general perturbations, the coordinates of a planet in space are given by trigonometric series, in which the time remains an algebraic symbol. To find where the planet is at any time it is only necessary to substitute a number in the formulae; the number expresses the number of years and fractions thereof since some initial epoch, say 1900 January 1, Greenwich mean noon. It is this method that has been most used for the principal planets. The latest application to Jupiter and Saturn was made about 60 years ago by G. W. Hill, an eminent mathematical astronomer then employed in the U. S. Nautical Almanac Office. His formula for the position of Saturn requires seven large pages, printed in small type, and the tables that he devised for easy evaluation of the formula fill up 84 pages. These tables have been used for more than 50 years to calculate the positions of Saturn published each year in the navigational almanacs.

The method of general perturbations suffers from two drawbacks. In the first place the amount of calculation is very considerable (Hill spent eight years developing his theory of Jupiter and Saturn), and it is very difficult to be sure that all of the appreciable effects have been taken into account. Comparison of Hill's tables of Saturn with observations of this planet, for example, shows that the tables are in error by continually increasing amounts. The errors, though small, are of theoretical importance, and before many more years will be large enough to be of practical importance as well. Similarly, Newcomb's tables of Uranus and Neptune, constructed about 50 years ago, show increasingly large errors. The errors must be due to defects in the theory, but the precise nature of the trouble is not yet clear in every case.

The second drawback of the method of general perturbations, as it has so far been applied to planetary motions, is that the formula can be used for only a limited period, perhaps a few hundred years on either side of the initial epoch, without serious loss of accuracy. The method is without value for tracing the motions of the planets over hundreds of thousands of years, or even millions, as we should like to do. It is probable that the limitation is not inherent in the method itself; several ways have been suggested for overcoming it, but a truly frightful amount of calculation would be involved. Electronic calculators may solve the problem eventually, but even the task of setting up a machine to do the calculations automatically is a staggering one.

The other method that has been used for tracing planetary motions is called the method of special perturbations. Here the position of a planet is actually calculated step by step from the initial epoch, the steps being so close together that the planet does not move far enough from one step to the next to change the attractions of the other planets upon it very much. This method also has two drawbacks. In order to find the position of a planet at any time it is necessary to calculate it for all the intervening times since the initial epoch; and if many steps are required it is necessary to use many significant figures in the calculations, to avoid excessive accumulation of error in the end-figures.

The method of special perturbations has not been much used for the principal planets; its applications have usually been to the minor planets and to comets, where the number of steps is not very great, and where the highest precision has not in general been required. In these applications it is assumed that the positions of the disturbing planets are already well enough known, so that at each step it has been necessary only to calculate the attractions of the principal planets (and of the sun) on the body being studied. The masses of the minor planets and comets are so small that they do not disturb each other, or the principal planets, appreciably.

During the past three years, an application of the method of special perturbations has been made to the five outer planets of the solar system, Jupiter, Saturn, Uranus, Neptune, and Pluto, as a portion of a co-operative undertaking, sponsored by the Office of Naval Research, of the U. S. Naval Observatory, the Yale University Observatory, and the Watson Scientific Computing Laboratory. The paths of these five planets have been traced out for 407 years, from 1653 to 2060, by calculating their actual positions at 40-day intervals. These five planets were chosen because the first four are the controlling bodies of the solar system (except for the sun), each being far more massive than all the other five principal planets and remaining material put together, while Pluto, the outermost, of relatively small mass, yet exerts appreciable effects on the others. The effects of the remaining principal planets, Mercury, Venus, Earth, and Mars, are hardly appreciable, and can best be worked in separately from the main problem.

The present application is by far the most extensive that has ever been made of the method of special perturbations. It is the first application in which the actions of the planets on one another have been calculated at each step, instead of assuming that the paths of all except one are known in advance. Thus, at each step, the attraction of each of the five planets on the other four was calculated, as well as the attraction of each on the sun. Each step of the integration involved 800 multiplications of large numbers, 100 divisions, 1,200 additions and subtractions, and the recording of 3,200 digits. The large number of steps made it necessary to use 14 decimals in the calculations.

So large an amount of calculation could not have been accomplished in a reasonable length of time without an electronic calculator of high capacity. Fortunately, such a calculator was placed in operation in January, 1948. This machine, the IBM Selective Sequence Electronic Calculator, was made available without cost to the project by Thomas J. Watson, chairman of the board of the International Business Machines Corporation. The SSEC was able to make all the calculations, in duplicate, for a single 40-day step in less than three minutes. At each step the machine automatically compared the two independent results, and in case of disagreement it automatically repeated the calculation. Even electronic calculators make mistakes occasionally, but it was found that the machine was able to correct most of its mistakes on the second attempt. In case of disagreement on the second trial the machine stopped, indicating need for servicing.

In order to judge the efficiency of the machine, several estimates were made of the time required to do the calculation in the ordinary way, with an electric desk calculator. It appears that the ratio is in favor of the electronic calculator, by about 1,000 to one; in other words, an operator with a desk machine, working 40 hours a week, might have done the job in about 80 years, if he had made no mistakes. Ex-

ISOLATED*

A lovely hermit globular
Is 2419,
Which vastly far across the dark
Sends telescopic sheen;
A starry sphere that lives alone
And seems to like its plight,
With fifty thousand suns or more
To spark its superlight.
An introvert, a spatial tramp —
Such names are truly pat,
But 2419 shines on,
Oblivious to that.

L. S. COPELAND

*Inspired by the May, 1950, back-cover picture.

perience shows, however, that in work of this kind the occurrence of mistakes may double the time required. Furthermore, a mistake occurring at any step causes every subsequent step to be wrong. It is not certain that this work could have been successfully accomplished at all by ordinary methods.

As was mentioned earlier, the initial data required for solving the problem are the position, speed, and direction of motion for each planet at some initial epoch. Three numbers are needed to specify the position, one for the speed, and two for the direction, making a total of six numbers for each planet, or 30 numbers in all. These 30 numbers have to be determined by observing the planets with telescopes. When much accuracy is wanted it is necessary to have many observations, extending over a long period of time, and this is one reason why the calculations were extended so far into the past. The 30 constants of the orbits were known at the start with insufficient accuracy, and were improved by successive approximations. The first calculation extended for only 30 years. The resulting positions of the planets were compared with the observed positions, and the constants of the orbits were adjusted to bring about better agreement. A second calculation was then commenced, and carried for 180 years, after which a new comparison with observations was made, and the constants adjusted a second time. Another calculation was then made for the same 180 years, and another comparison with observations showed that the constants needed no further improvement. The final step was to extend the 180-year stretch to 400 years.

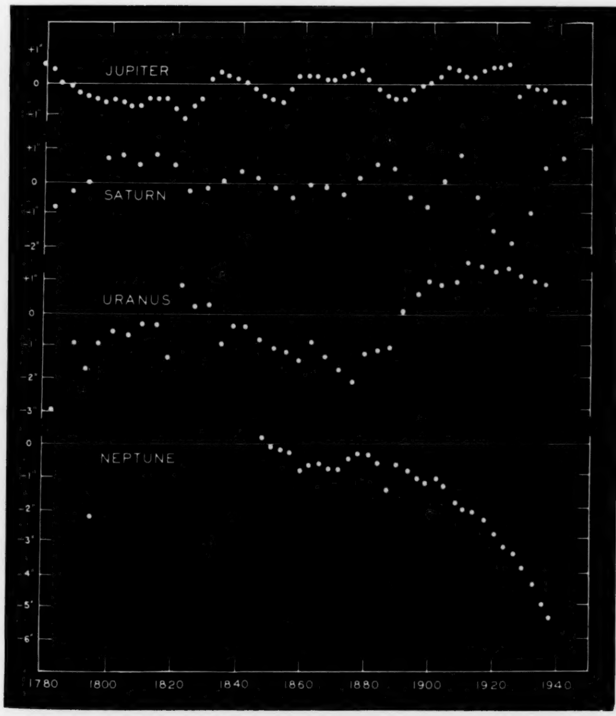
About 15,000 observations of Jupiter and Saturn were used in adjusting the constants of the orbits. For Uranus and Neptune fewer observations were available. Uranus was not discovered until 1781, and Neptune not until 1846. For Pluto the number of observations was comparatively small, as this planet was discovered in 1930. For this reason it may be expected that the calculations for Pluto will prove to be less accurate than the others, and by the year 2060 the error may be quite appreciable. It was still worthwhile to include Pluto in the work, however, on account of its influence on the other four planets; its motion is known with ample accuracy for this purpose.

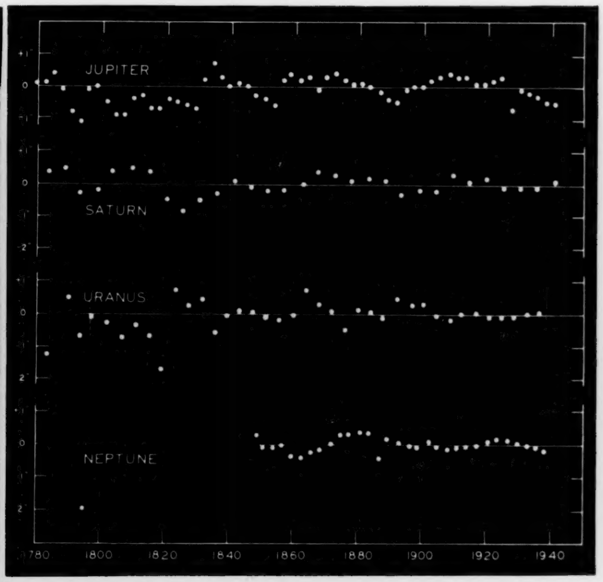
The adjustment of the constants of the orbits by comparison with observations is a task of considerable magnitude. It has not yet been practicable to use electronic machines for this sort of work, because too much discriminating judgment is needed at nearly every stage. Several thousand hours of labor by expert astronomers were necessary in all, not counting the labor that had been required to make the observations in the first place, which was even greater. Fortunately, however, much of the work had already been done several years earlier, with this very object in view; and during the course of the electronic calculations only a few hundred hours of an astronomer's time were needed. This work was done at the Yale Observatory and the Naval Observatory, principally by the two authors. The electronic calculations were planned and directed by Dr. W. J. Eckert, director of pure science, International Business Machines Corporation.

The two charts contrast the representation of the observations by the planetary tables and by the numerical integration. A positive value of a residual indicates that the observed position in the orbit is ahead of the calculation.

Concerning the diagrams of observations compared with planetary tables, the following remarks may be made. The plots for Jupiter and Saturn are of a somewhat different type from those for Uranus and Neptune. For the former two planets, the differences *observations minus tables* were read from a smoothed curve drawn through the numerous residuals that represented the deviations from the tables for every year. Moreover, they were subsequently modified by a provisional adjustment of the elliptic motion which serves as the basis of the tables. In the case of Sat-

The diagrams below show (left) the residuals between the observed longitudes of four planets and their predicted positions according to the planetary tables of Hill (Jupiter and Saturn) and Newcomb (Uranus and Neptune), and (right) the residuals when observed positions are compared with longitudes from the orbits numerically integrated by the SSEC. The plots extend back to about the time of the discovery of Uranus. Were predictions and observations to agree exactly, the points would be plotted on the horizontal line of zero residual in each case.





Note the much closer agreement of the observed positions with the newly computed orbits. The improvement in observations about 1840 evident in the above curves was due to the introduction of the electric chronograph; that about 1900 came as a result of the invention of the traveling-wire micrometer.

urn this brings out very clearly the inability of the tables to represent the observed positions. For Uranus and Neptune the plotted residuals represent the deviations from the tables without any smoothing or adjustment. In the case of Uranus, such an adjustment would have produced a considerable improvement. The deviation of the path of Neptune from the tables since 1900 must be ascribed primarily to the omission of the attraction by Pluto from the tables. Pluto's existence was, of course, unknown 50 years ago, when the tables for Neptune were constructed. Finally, the observations of Neptune that were available when Newcomb constructed the tables covered only 50 years since its discovery in 1846. There are, however, two precious pre-discovery observations by Lalande in 1795, when the planet was recorded as a 9th-magnitude star in the course of a series of observations of faint stars. The curious situation with regard to Neptune is that the modern observations of this planet and the pre-discovery observations of 1795 are compatible only if the attraction by Pluto with a mass comparable with the mass of the earth is included (see *Sky and Telescope,* March, 1950, page 103).

Turning now to the diagrams of observations compared with the numerical integration, two points of importance should be kept in mind. First, the observations of Jupiter are considerably less accurate than those of the other planets, primarily because of the large size of its disk. Second, there was a considerable improvement in the quality of the observations about 1840 and again about 1900. In this light, the residuals for Saturn and especially Uranus look entirely normal: large scatter before 1840, improved representation from 1840 to 1900, and further improvement since 1900. While the improvement since 1900 is also well noticeable in the case of Neptune, the residuals for this planet seem to have a systematic character. This may be because Neptune moves so slowly among the stars, only two degrees a year. Thus, for many years the observations of the planet are based upon a comparison with the same stars in the same part of the sky. This tends to carry into the residuals the small systematic errors in the star positions.

The comparison with the observations as shown in the diagrams does not exhaust the subject; further work remains to be done. It was mentioned that in addition to the constants of the orbits, the masses of the planets must be known at the outset. Fortunately, reasonably good values of these were available from previous investigations. The results of the present work will, however, make further improvement possible, when a more refined analysis can be made. In this connection, about a dozen observations of Uranus during the century preceding its discovery may be of particular worth for the evaluation of the mass of Pluto. These observations were made under circumstances similar to those pertaining to Neptune in 1795. Although they are of low accuracy compared with modern observations, their early date makes them at least interesting. The calculations in connection with these have not yet been completed.

As to the value of the work, there are the basic scientific value and the immediate practical value. From the scientific point of view, the object of studying the motions of celestial bodies is to learn more about how the universe operates. For 200 years after Newton's formulation of his laws of motion it was thought that they would suffice to explain all of the celestial motions. The astronomer Leverrier discovered, however, about 100 years ago, after many years of study, that the planet Mercury did not move strictly in accordance with Newton's laws. The discrepancy remained unexplained until 1915, when Einstein formulated the general theory of relativity. Then it appeared that the discrepancy could be completely removed. But what is meant by complete removal? Only that the contradictions, if they exist, are smaller than the errors of the observations. As the observations continue to improve with the invention of new techniques, it is always possible that a discrepancy will arise where none was known before. Then attempts to explain it may lead to a fundamental advance in knowledge. It is along this general pattern that all of the sciences, biological and social as well as physical, advance.

It is known that gravitation is not the only force acting within the solar system. For example, the presence of meteors and the zodiacal light indicate something in the nature of a resisting medium. Whether this is dense enough to affect the motions of the planets appreciably is not known. The present work may help to provide an answer. And there may be other forces acting, at present unknown.

As to its practical value, the present work will suffice, so far as these planets are concerned, for the foreseeable needs of navigation for the next 100 years.

The Paris conference on the fundamental constants of astronomy in March, 1950, recommended that the new ephemerides of the five outer planets be made the international standard. If this recommendation is adopted by the International Astronomical Union, about 10 years will probably be required before the new data appear in the *American Ephemeris.*

Published by courtesy of "Research Reviews," Office of Naval Research.

TOTAL ECLIPSES FOR 10 YEARS AHEAD

The *Circulars* of the U. S. Naval Observatory give the tracks of total solar eclipse paths for the next 10 years (see Nos. 1, 2, and 16, 1949-50). In this period there will be six such eclipses, but the path of one of them, for June 8, 1956, lies wholly in the South Pacific Ocean without crossing any land. There will be no total eclipses of the sun in 1951, 1953, 1957, or 1960.

The eclipse of February 25, 1952, starts in the Atlantic Ocean between South America and Africa; has maximum duration near Khartoum, Anglo-Egyptian Sudan, of three minutes, 10 seconds; ends in Irkutsk, U.S.S.R.

That of June 30, 1954, starts in Holt County, Neb., passes northeast over Canada and the tip of Greenland; has maximum duration of two minutes, 35 seconds, near the Shetland Islands, and ends near Jodhpur, India.

On June 20, 1955, a notably long eclipse starts in the Indian Ocean; has maximum duration on land in the Philippines, seven minutes, two seconds; ends near the Fiji Islands.

The eclipse of October 12, 1958, starts north of the Solomon Islands in the South Pacific, reaches maximum duration of three minutes, 30 seconds near the Society Islands, and ends in Argentina.

Starting in Gardner, Mass., on October 2, 1959, the shadow of the moon crosses the Atlantic Ocean to the Sahara, the eclipse having a duration of three minutes, two seconds in the French Sudan, and ending in the Arabian Sea.

FRANK S. HOGG DIES

The director of the David Dunlap Observatory, University of Toronto, Dr. Frank S. Hogg, died on the first day of this year, at the age of 46. He is survived by his wife, Dr. Helen Sawyer Hogg, also an astronomer, and three children.

Dr. Hogg's death occurred from a heart attack, following a case of bronchitis, five years to the day after he assumed his duties as head of the department of astronomy at the university and director of the observatory.

NEWS NOTES

By Dorrit Hoffleit

HIGH-ALTITUDE STATIONS

Cosmic-ray physicist Serge A. Korff, in the November issue of ***Physics Today,*** describes the distribution of high-altitude stations all over the earth. Such stations are valuable to scientists in nearly all fields, although astronomers and cosmic-ray workers have most felt their need. Particularly for the latter a fairly even distribution of such stations is important, whereas the existing installations are grouped together and the less populated parts of the globe have none.

From 9,000 to 12,000 feet are the Jungfraujoch, Switzerland; Echo Lake, Colo.; Climax, Colo.; Huancayo, Peru; Sacramento Peak, N.M.; Pic du Midi, France; Testa Grigia, Italy; Chamonix, France. At 14,156 feet on Mt. Evans in Colorado is the highest regularly operating station, but temporary observations have been made from such heights as 19,000 feet on Denali Pass, Mt. McKinley, Alaska; 19,200 feet on the summit of El Misti, Peru.

Among the many locations being considered for permanent cosmic-ray stations, Dr. Korff mentions the Himalayas as being of special value in providing sites halfway around the world in longitude from the Americas. More stations on some of the 50 peaks higher than 14,000 feet in the United States would also be of great service.

ST. MICHEL OBSERVATORY

In October, the main dome of the largest observatory in France was dedicated. It houses a 48-inch reflector that was described in ***Sky and Telescope*** in July, 1945. The St. Michel Observatory will eventually have three domes, and its main structure will include laboratories and precision - instrument workshops. The observatory is located in Haute Provence, three miles southwest of Forcalquier.

METEORITE CRATER FORMATION

Does a meteorite vaporize when it strikes the earth at high velocity? If it does not, does it shatter or suffer severe deformation? Can one, from the size and shape of the resultant crater, determine the mass, velocity, or energy of the meteorite? What are the chances of locating the meteorite and where should one search for it?

These are the questions discussed by John S. Rinehart, of the Naval Ordnance Test Station at China Lake, Calif., in an article, "Some Observations on High-Speed Impact," in the Contributions of the Meteoritical Society in ***Popular Astronomy*** for November. Although experimental data involve for the most part smaller masses than those producing the largest meteorite craters, and relatively low velocities, Rinehart's studies have led to several significant conclusions. Only a small fraction of the meteorite is vaporized on impact, and the energy released by burning does not contribute significantly to the energy involved in crater formation. The size or volume of the crater indicates rather closely the striking or kinetic energy of the meteorite. Finally, as suggested by R. B. Baldwin, there is some likelihood that high-velocity meteorites do not imbed themselves in their craters, but are ejected and land some distance away.

MAGELLANIC CLOUDS

A significant difference between the Large and the Small Magellanic Clouds was reported by Director Harlow Shapley to Harvard Observatory's visiting committee recently. The Small Cloud is practically free of the interstellar dust clouds that are now commonly considered the stuff from which new supergiant stars are being built up, while the Large Cloud has a great deal of such material.

On plates showing stars down to magnitude 17.5, about 30 faint distant galaxies per square degree can be seen in the vicinity of the Large Cloud. On the other hand, only three or four galaxies per square degree are able to shine through the "smog" of its central regions. Supergiant stars are numerous in the Large Cloud, but, surmises Dr. Shapley, "In the Small Cloud, the epoch of star birth has passed."

HAYDEN PLANETARIUM HEAD APPOINTED

Robert R. Coles, acting head of the Hayden Planetarium, has been named chairman, it was recently announced by the American Museum of Natural History. A member of the museum staff since 1929, Mr. Coles has been at the planetarium since 1936, and has given over 5,000 regular planetarium demonstrations. Serving with the U. S. Air Force from 1942 to 1945, Mr. Coles thereafter played an important part in the planetarium's navigation training program for the armed forces.

REAL DEEP FREEZE

A *cryostat* with a capacity of 15 cubic feet that can cool its contents to 452° below zero Fahrenheit and hold them at that temperature indefinitely has been built at Massachusetts Institute of Technology by Dr. Samuel C. Collins. The apparatus operates by compressing, regeneratively cooling, and then expanding helium gas until a portion of the gas turns into a liquid, which takes place when the helium is just 7.5 degrees above absolute zero of −459.6° F. The new machine fills the need for a large space in which to study the behavior of heavy equipment at very low temperatures.

ELECTRIC SPACESHIP

Once outside the earth's atmosphere and in an orbit circling the earth, a spaceship might be controlled by its reaction to electrostatically repelled particles, according to a suggestion by Hermann Oberth, German rocket pioneer and expert. He suggests that the sun provide the electrical energy by warming the junctions of several hundred thousand thermocouples joined in series and wound around the outside of the ship. The resulting potential difference would be applied to electrodes porous to the electric particles that would be thereby expelled from the ship.

In air, electrostatic generators can create electron "winds" strong enough to blow out a candle, while in highly evacuated Geissler tubes molecules and atoms escaping from the anode develop mean velocities of 30 to 250 miles a second, and the cathode emits electrons with velocities up to 56,000 miles a second.

The pros and cons of Oberth's suggestion are discussed by him in detail in a two-part article in ***Radio-Electronics*** starting in December.

BUREAU OF STANDARDS SEMICENTENNIAL

On March 3, 1901, by Act of Congress, the National Bureau of Standards was created as the principal agency of the federal government for fundamental research in physics, mathematics, chemistry, and engineering. The history of the bureau, however, extends back to the Constitution, which gave cognizance of weights and measures to the federal government. The immediate antecedent of the bureau was the Office of Weights and Measures, established in 1830.

In recognition of the role of the Bureau of Standards in the progress of science in America, some 25 scientific and technical societies are planning to hold their meetings in Washington this year. Among them are:

Optical Society of America, March 1 - 3

Union Radio Scientifique Internationale, April 16 - 18

National Academy of Sciences, April 23 - 25

Horological Institute of America, May 14 - 15

National Conference on Weights and Measures, May 22 - 25

American Astronomical Society, June 21 - 23

Institute of Mathematical Statistics, October 26 - 27

American Mathematical Society, October 27

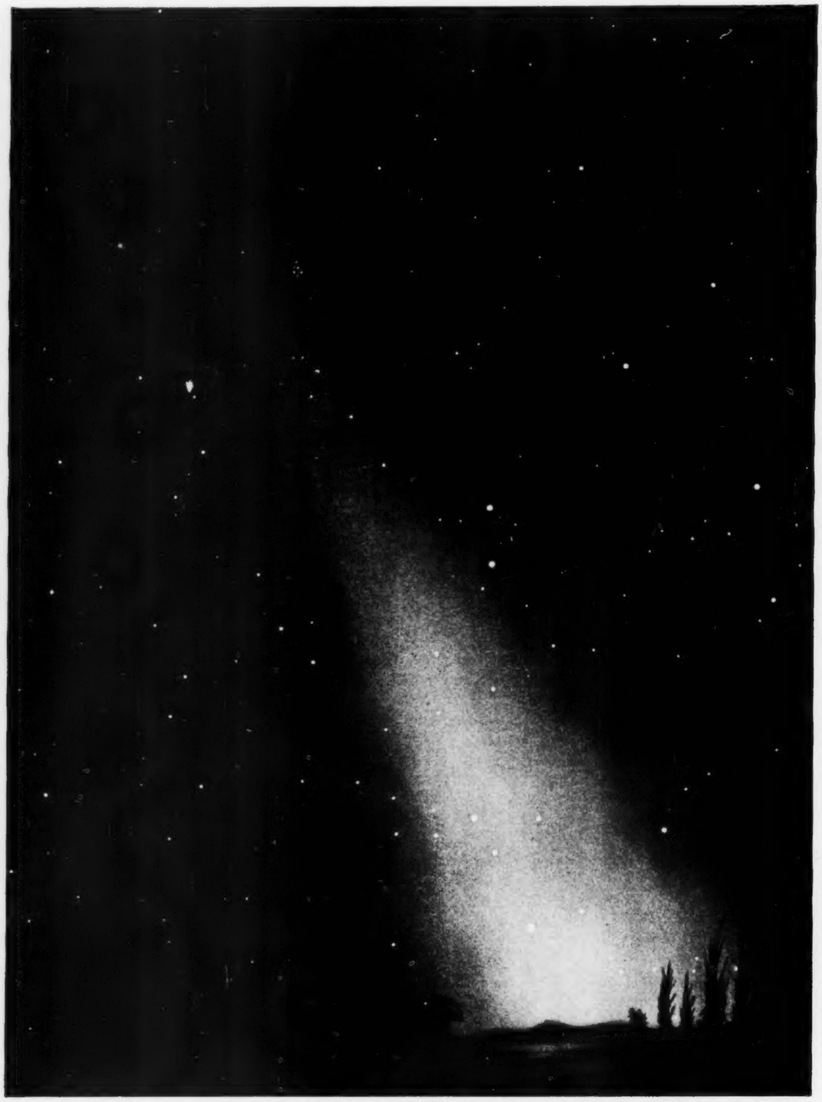
DUST IN THE SOLAR SYSTEM

By Otto Struve, *Berkeley Astronomical Department, University of California*

AT ABOUT 4:30 on January 16, 1950, the Japanese astronomer Tsuneo Saheki noticed an enormous yellowish-gray cloud extending over the southern limb of Mars and reaching an elevation above the planet's surface of more than 100 kilometers, with a horizontal extent of about 1,500 kilometers. Although Mr. Saheki observed Mars for several hours, he felt sure that the cloud was not visible before 4 o'clock Japanese standard time.

This information became available to American observers a few days later, through a brief report issued by W. H. Haas, director of the Association of Lunar and Planetary Observers. But because of the great similarity of the periods of axial rotation of Mars and the earth (24 hours 37 minutes compared with 24 hours), the region of the planet where the cloud was observed did not become accessible to American observers until about three weeks later. At that time, early in February, C. W. Tombaugh at Las Cruces, N. M., and others saw "nothing unusual about the planet . . . apparently the cloud had dissipated."

Although an effort was made at the time by a few newspapers to make a sensation of Saheki's observation — perhaps related to an atomic explosion on Mars — the truth is that clouds of a yellowish tinge are often observed on the planet, though not usually at a height of many miles. It has been customary to think of these clouds as consisting of finely divided dust swept up by the winds on the planet's surface. Whether this interpretation is correct remains to be seen. Some investigators have expressed doubt that the relatively feeble winds on Mars would be able to lift large masses of dust several miles above the planet's surface.



The zodiacal light, here drawn by Trouvelot, extends along the ecliptic. Early spring evenings after sunset are favorable for its observation from mid-northern latitudes.

In a short paper in the *Irish Astronomical Journal,* March, 1950, a new interpretation comes from E. J. Opik, which was briefly described in *Sky and Telescope,* September, 1950, page 273. He rejects Saheki's suggestion that the cloud may have been of volcanic origin, and in this most astronomers will agree with him. Mighty volcanic cones, like Orizaba and Popocatepetl, are absent on Mars. Moreover, the scarcity of water on the planet renders any volcanic action inherently improbable. Instead, Opik calls attention to the possibility of a violent impact upon Mars of a large meteorite, with the consequent lifting into the Martian atmosphere of huge quantities of shattered rock and surface dust.

Once again we have the question of "worlds in collision" and the resulting fragmentation of planetary and meteoric bodies. It is a bizarre coincidence that 1950, which produced the much-discussed Velikovsky book of science fiction, also produced a deluge of sound papers on various problems connected with collisions within the solar system, most of which have been reported in this magazine. Thus, in the October issue of the *Astronomical Journal,* Whipple and Hamid discuss the effects of encounters of Comet Encke, or its possible companions, with small minor planets, about 4,700 and 1,500 years ago; G. P. Kuiper explains the origin of the present ring of minor planets as the result of collisions among several larger bodies which were originally formed between two and 3½ astronomical units from the sun; and D. Brouwer extends his work on Hirayama's families of minor planets, with the result that Kuiper's theory of a collisional origin of these families can be regarded as consistent with the observations.

The most extensive investigation of "Collision Probabilities with the Planets and the Distribution of Interplanetary Matter," by Opik, was read by title last May at the Royal Irish Academy in Dublin. This paper is as yet unpublished, but its results are referred to in

the shorter article in the *Irish Astronomical Journal.* Moreover, Dr. Opik was kind enough to furnish me with a copy of his complete manuscript.

Finally, in several recent articles in the *Astronomical Journal* of the Soviet Union and the annual volumes entitled "Ouspekhi Astronomicheskikh Nauk," V. G. Fessenkoff has discussed his hypothesis of the formation of zodiacal particles as the result of collisions between minor planets and meteors.

All of these theories have one thing in common. They assume that there existed, and even now exist, solid bodies in the solar system whose orbits intersect in such a manner as to produce occasional collisions. As in a gravel mill, the result of these collisions is the gradual shattering of the large bodies and the formation of smaller fragments with a certain amount of finely divided dust.

It has been known for a long time that the surface of the moon must be covered with a fairly thick layer of powdery dust, whose particles may have diameters of the order of 1/10 millimeter or less. The best evidence comes from the radiometric observations of the moon by Pettit and Nicholson over 20 years ago, and from similar observations by Pettit during a lunar eclipse on October 28, 1939. The earlier observations were interpreted in 1929 by P. Epstein. Two years ago, A. J. Wesselink published a new theory of the heat conductivity of lunar surface layers based upon the Mount Wilson data. The mathematical theory of the transfer of heat through a solid body is, in principle, quite simple, although the details require the solution of a famous differential equation that, in 1822, led J. B. J. Fourier to develop the mathematical series known by his name.

In the case of the moon, the surface is heated by a variable source, depending upon the height of the sun above the point on the surface of the moon for which observations have been secured. The heat gradually penetrates into deeper layers, with a certain time lag, so that the curve of temperature variation at a point below the surface has a smaller amplitude, and a displaced maximum, compared with the curve representing the variation of the surface temperature. When the heat is cut off, at night or during an eclipse, the heated layers of the moon continue radiating back into space the energy stored during the day.

The observed temperature of a point near the center of the lunar disk agrees fairly well with the continuous curve, in the accompanying chart from Wesselink's paper. Notice that during the eclipse the temperature drops suddenly from about 370° absolute to less than 200°, but it does not drop to absolute zero, as would be the case if the thermal conductivity were precisely zero and, consequently, no energy could be stored in the surface layers. Similarly, during the lunar night, between phases 0.25 and 0.75, the temperature drops to about 100°, but it does not go down to absolute zero. Some heat, though surprisingly little, is stored in the moon's surface material. The dashes indicate the form the temperature curve would have if the conductivity were zero.

It should be remembered that this case is altogether different from that of the earth or of any of the other planets with atmospheres. Air provides an efficient blanket with a greenhouse effect, for it transmits much of the incident short-wave radiation but prevents the escape into space of the outgoing long-wave radiation from the planet's surface.

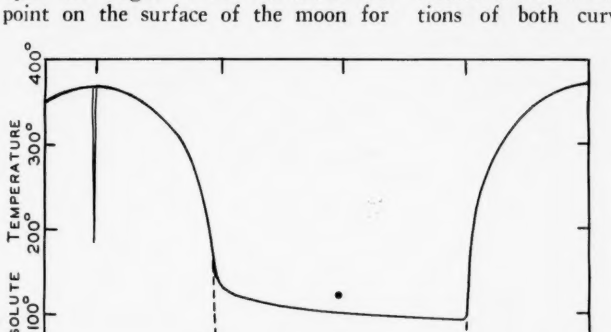
Wesselink's results show that the heat-storing property of the lunar surface is not zero. But it is smaller than that of any known substance on the surface of the earth! If our ordinary rocks formed the lunar surface, the lower portions of both curves on the graphs would be considerably higher. This seems strange until we consider that the moon has no air. It turns out that the terrestrial conductivity of white sand is about 300 times greater than the heat conductivity of the moon's surface. But on the earth the interstices between the individual grains of sand are filled with air, and this aids enormously in the transfer of heat from one particle to the next.

The Polish physicist M. Smoluchowski found, a long time ago, that when the air is removed from a powdery substance its conductivity decreases greatly. In a complete vacuum the transfer from grain to grain occurs by conduction at the small points where the grains touch one another, and through radiation within the empty interstices. The result is quite similar to the conductivity of the material on the moon.

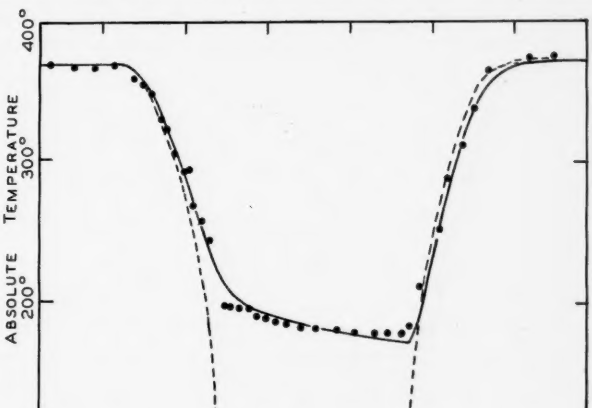
As a consequence of my preparing this article for *Sky and Telescope,* Dr. Wesselink has communicated to me another, novel idea, which first originated with Professor M. Minnaert in Utrecht. Because of the smaller surface gravity on the moon, the grains of dust will be less firmly packed on top of each other than is normally the case on the earth. Thus the points of contact of separate grains are less efficient in conducting heat on the moon than on the earth. At any rate, the moon is certainly covered with a layer of dust, perhaps about three inches in thickness.

Undoubtedly, the extreme variations in temperature of the moon's surface tend to break up the surface layers. The fragments roll down, and produce the relatively gentle slopes which we observe. But Opik remarks that this process does not lead to any large quantity of dust; it forms shale but not a layer of powdery dust.

The only known process of dust formation on the moon is the shattering action of meteorites. We can easily imag-



The calculated surface temperature of an area of the moon near the center of its disk during 1.1 lunations. At phase 0.0 the 1939 eclipse is drawn on the same scale, and at phase 0.5 (lunar midnight) is a dot showing Pettit and Nicholson's measured temperature. Diagrams from the "Bulletin" of the Netherlands Astronomical Institutes.



Observed temperatures (dots) during the 1939 eclipse agree well with the theoretical curve.

ine what would happen if a chunk of matter, like the Siberian meteorite of 1947, should strike the surface of the moon. The rocks would be shattered and "rock-flour" similar to that found in the Barringer Meteor Crater in Arizona would be produced in amounts exceeding by a factor of 100 or 1,000 the weight of the original meteorite. But at the present rate of meteorite impacts, Opik estimates that in a period of two or three billion years — roughly the age of the solar system — a layer not more than one millimeter in thickness could have been formed on the moon.

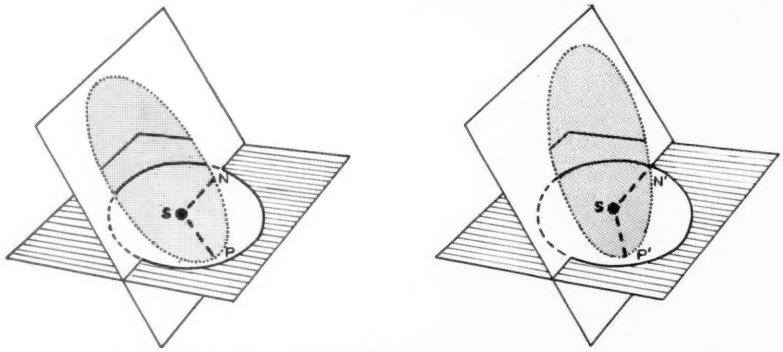
Opik has computed the probabilities of collision between known minor planets and all the larger planets. There are 27 asteroids whose orbits cross the orbit of Mars. As a rule, the inclinations at the present time are such that no collisions will result. But secular perturbations of the orbit of a minor planet or meteor produce a change in the longitude of perihelion and in the longitude of the node. Hence, the angle between the line of nodes (where the two orbital planes intersect) and the direction toward the perihelion (the line of apsides) undergoes a slow but continuous change, usually in the direction of increasing the angle. This effect is illustrated in the accompanying diagrams.

Thus, as a result of the slow perturbations by the major planets, there may result a point of intersection of the orbits of a minor planet or a meteor and a principal planet, such as the earth or Mars. A collision can occur if the planet and the smaller body are simultaneously at the point of intersection.

Opik has computed the probability that this will actually happen. For Mars and any one elliptically moving minor planet or meteor, the chances are that there will be one collision in about 10 billion years — not often enough to destroy all elliptically moving small bodies within the lifetime of the solar system. Hence, he believes that even now collisions of the sort considered are fairly frequent on Mars, because of Mars' location near the asteroid belt. The yellow cloud seen by Saheki may have been the result of such a collision.

In the case of the earth, or Venus, Opik's computations give one collision for every elliptically moving small body once in every 100 million years. Hence, he believes that these inner planets have effectively swept up all the smaller bodies within their domains during the three billion years the process has been going on. Collisions are now quite rare, though a billion years ago they may have been as frequent as they are now on Mars. The pockmarks of these ancient collisions on the earth have long ago been obliterated by erosion; on the moon, where ordinary erosion does not exist, we still see the evidence directly in the form of craters and, indirectly, in the thick layer of dust inferred from the Mount Wilson temperature measurements.

Undoubtedly, when a fairly large meteor or minor planet collides with the moon, the earth, or with Mars, large quantities of dust are thrown up, and some of it may have a velocity exceeding that of escape. Such dust will leave the parent planet forever and become a diffuse cloud of finely divided particles, all traveling in Keplerian orbits around the sun. This process is not now important in the case of the earth and the moon; and even in the case of Mars the amount of interplanetary dust created in this manner is not sufficient to explain the existence of the zodiacal light.



Two orbits are here shown schematically. At the left the shaded one "fits" easily inside the other, with no point of intersection. At the right the orbit has been shifted in its plane in such a way that the angle NSP, between the line of nodes and the perihelion direction, has increased to N'SP', and the two orbits intersect at N', where a collision is thus possible.

But here we encounter an interesting idea first explored by Fessenkoff. The number of minor planets is very great. About 2,000 of the brightest have been catalogued, but according to W. Baade there must be at least 30,000 or 40,000 of these objects easily observable with the Mount Wilson 100-inch telescope (that is, down to about magnitude 19). The total mass of these objects is only a fraction of the mass of the earth; Fessenkoff estimates that it may be about one tenth, from the irregularities in the motion of Mars, but a previous estimate by H. N. Russell is about 50 times smaller. Yet the combined surface area of all these objects, exposed to the bombardment of each other and of meteoric fragments, is many times greater than the surface area of all the major planets and their satellites combined.

That this must be the case is evident when we compare the volume and surface area of a sphere. Halving the volume of a spherical particle by forming it into equal spheres of smaller radius results in an increase in the total surface area by a factor equal to the cube root of 2, or about 1¼ times. Thus, successive fragmentations produce an increase of the exposed surface.

Hence, the minor planets are peculiarly exposed to collisions. Moreover, their small individual masses are incapable of retaining any dust formed by the impacts. The dust escapes into space, and undoubtedly tends to augment the zodiacal light medium.

Fessenkoff has computed the distribution of the dust within the solar system that would result from a uniform explosion, in all directions, with a given velocity, from a typical minor planet. For example, those dust particles that escape from the parent body with a velocity equal to that of the latter, assumed to be in a circular orbit, lead to a heavy concentration of dust near the sun, a thinning out at intermediate distances, and a ringlike concentration in the region where the minor planets abound. This distribution agrees with the observed density of the medium producing the zodiacal light.

The density of this medium does not, however, go on increasing with time, for two effects tend to keep the density constant. The first is the repulsive action of light pressure upon very small particles. These, of dimensions less than about 10^{-5} centimeter, are driven away by radiation pressure and go off in hyperbolic paths, to become part of the *interstellar* cloud of dust. The second is the Poynting-Robertson effect on larger particles. This phenomenon is related to the aberration of light: More light quanta from the sun fall on a particle on its forward-moving side than fall upon it from the opposite direction. Hence the radiation pressure tends to impede its forward motion, and it slowly spirals toward the sun. The effect is the same as that encountered by a person walking rapidly in a heavy downpour of rain — the droplets hit his face and tend to slow his progress.

It is difficult to give an adequate qualitative explanation of this phenomenon without the use of relativity. Moreover, the axial rotation of the sun produces a Doppler effect, as seen from the particle, which differs for the two hemispheres of the sun — the advancing

and receding ones — and this, as D. Alter has shown, somewhat counteracts the Poynting-Robertson effect. Finally, Opik has called attention to what he calls the Yarkovsky effect, which results from the rotation of the particle itself; the evening (backward) side of a rotating particle radiates more heat than the opposite, morning side. Since radiation carries with it a certain "quantity of motion," or momentum, the particle receives a slight acceleration forward in its orbit as a result of its reaction to the greater radiation leaving on the backward side.

However, despite these complications, all theoreticians agree that in some millions of years even fairly large particles would have had time to fall into the sun, or be captured by Jupiter. The zodiacal light would have disappeared long ago if it were not continuously replenished. (The origin of the zodiacal light from cometary debris is a theory recently proposed by Whipple; page 94.)

In reality, the particles will not actually fall into the sun. All but the largest will be volatilized by the sun's heat before they reach its surface. As Russell showed 20 years ago, the temperature of a meteor at a distance of one astronomical unit (150 million kilometers) from the sun is 400° absolute, but at only 700,000 kilometers it is 4,050°. The gaseous atoms resulting from the evaporating of a particle will be subjected to radiation pressure, in a manner that depends on their spectra, and some, if not all, will be driven out of the solar system.

Thus, our solar system acts as a gravel mill, and produces dust through the process of shattering of larger solid bodies. There is not now any evidence that within the system dust is being newly formed through the processes of accretion and absorption which many astronomers have used to explain the existence of the opaque *interstellar* clouds of finely divided material. Undoubtedly, the smallest residues of our solar gravel mill are thrown out into the galaxy to form part of the interstellar clouds, but this contribution to these clouds is quite insignificant at the present time. Conceivably, however, other star systems produce more gravel-mill dust.

It is not now possible to estimate the total amount of this kind of interstellar dust. Its properties — irregularity in shape, characteristic distribution of sizes, chemical composition, and mineralogical structure — must differ greatly from those of particles that are formed by an orderly process of growth when a few atoms stick together, gradually building up a large molecule and finally producing a particle of what the Dutch astrophysicists have aptly described as interstellar smoke. Perhaps future observations will permit us to distinguish these two kinds of interstellar matter.

Amateur Astronomers

THIS MONTH'S MEETINGS

Cambridge, Mass.: At the February 1st meeting of the Bond Astronomical Club, 8:15 p.m. at Harvard Observatory, the motion picture, The Story of Palomar, will be shown, together with a film on the development of radio astronomy in Australia.

Chicago, Ill.: The Burnham Astronomical Society will meet February 11th at the Adler Planetarium, at 4 o'clock. Russell F. Anderson will speak on "Meteors."

Columbus, Ohio: The Columbus Astronomical Society, meeting on February 9th, Friday, at 8:00 p.m. at the McMillin Observatory, will hear a lecture on "Stellar Distances."

Dallas, Tex.: G. P. Fearis will show a motion picture, Interesting Things on Our Planet, at the February 26th meeting of the Texas Astronomical Society, at 8:00 p.m. in the Dallas Power and Light Company auditorium.

Detroit, Mich.: On February 11th, at 3:00 p.m. in State Hall of Wayne University, the Detroit Astronomical Society will hear Dr. L. H. Aller, of the University of Michigan, speak on "What Makes the Stars Shine?"

Geneva, Ill.: On Tuesday, February 6th, starting at 8 o'clock, there will be demonstrations of mirror making by members of the Fox Valley Astronomical Society telescope makers committee at the workshop of Dale Bufkin, 366 Hubbard St., Elgin.

Indianapolis, Ind.: Dr. Frank K. Edmondson, of Indiana University, will speak on "Weighing the Stars" at the February 4th meeting of the Indiana Astronomical Society, 2:30 p.m. in the Riley Library.

Madison, Wis.: At the February 14th meeting of the Madison Astronomical Society, 8 o'clock at Washburn Observatory, a question session will be held, with Harold Porterfield as master of ceremonies and the board of experts including Ed Baillie, A. E. Whitford, and C. M. Huffer.

New York, N. Y.: The Amateur Astronomers Association, meeting on February 7th at 8:00 p.m. in the American Museum of Natural History, will hear Walter Scott Houston, author of Deep-Sky Wonders in **Sky and Telescope,** discuss "Deep-Sky Wonders."

Philadelphia, Pa.: The 15th anniversary dinner of the Amateur Astronomers of the Franklin Institute will be held at 7:00 p.m., Thursday, February 1st, with Dr. James G. Baker, Harvard College Observatory, the principal speaker.

Pittsburgh, Pa.: Dr. N. E. Wagman, of Allegheny Observatory, will lecture on "Astrometric Binaries" at the February 9th meeting of the Amateur Astronomers Association of Pittsburgh, at the Buhl Planetarium at 8:00 p.m.

Rutherford, N. J.: The Astronomical Society of Rutherford will meet on February 1st at 8 o'clock in the Y.M.C.A. Mrs. Alice Fowler will discuss "Astrology: A Pseudo-Science or a Real Science?"

Sacramento, Calif.: As one of the public lectures of the Sacramento Valley Astronomical Society, Dr. O. J. Lee, University of California, will speak on "Astronomy as a Hobby," at 8 o'clock, February 6th, in the Little Theater, Sacramento Junior College.

Washington, D. C.: The National Capital Astronomers will meet on Saturday, February 3rd, in the Commerce Building auditorium at 8:00 p.m. Ernest G. Reuning, of the Army Map Service, will lecture on "Possibilities of Travel in Outer Space."

Worcester, Mass.: Meeting at the Natural History Museum on Tuesday, February 6th, at 8:00 p.m., the Aldrich Astronomical Society will hear R. Newton Mayall speak on "Skyshooting," the title of a book of which he is a co-author.

FORT WORTH OBSERVATORY AND PLANETARIUM

The City of Fort Worth has voted $300,000 in bonds for the construction of a new Children's Museum. The citizens are expected to donate another $200,000 to complete the building, which will include an observatory on the roof and a special planetarium room for 100 spectators. The Junior League has donated to the Children's Museum a Spitz planetarium projector, to be named in honor of Dr. Charlie M. Noble, a director and vice-president of the Ft. Worth Astronomical Society.

The honorary degree of doctor of laws was recently bestowed upon Miss Noble by Texas Christian University for her work in mathematics and astronomy. Miss Noble has been instrumental in introducing the teaching of astronomy in the public school system of the city, as well as in the establishment of the Junior Astronomy Club at the Children's Museum. This group meets every Friday night and has about 80 members.

PENNSYLVANIA SOCIETY

The Amateur Astronomers Association of Shaler Township meets on the third Friday of each month at 8 o'clock in the Cherry City firehouse. The group is particularly interested in promoting a good hobby for juniors and in acquainting them with amateur astronomy and telescope making.

The present membership is 11 seniors and 14 juniors. The president of the A.A.A. of Shaler Township is Cliff Raible, Rebecca Square, Millvale 9, Pa.

L.A.A.S. OFFICERS

Election of officers for 1951 was held by the Los Angeles Astronomical Society at its concluding 1950 meeting. The incoming president is Dr. Homer B. King, who had been vice-president. George Shuster, past treasurer, is now vice-president; Jackson Carl is the new treasurer, and Mark Stolle, recording secretary.

NEW LEAGUE MEMBERS

Two societies have recently become members of the Astronomical League. They are the Astronomical Society of Utah, Salt Lake City, which has 36 members, and the Astronomy Club of Fulton County, in Gloversville, N. Y., with 25 members.

International Telescope

AN ADVENTURE in international co-operation in astronomy and related affairs has culminated in the mounting of the first Baker-Schmidt type of telescope to go into operation in the Southern Hemisphere. It is known as the ADH, for it represents the combined planning of astronomers at three observatories, Armagh in North Ireland, Dunsink in Eire, and Harvard in Massachusetts. It will be used for observations in research programs of each of these observatories.

The front-cover picture shows the ADH as it is at present at the Boyden station of Harvard College Observatory in South Africa. Dr. J. S. Paraskevopoulos, superintendent of the Boyden station, is standing on the short ladder. Below him are, left to right, Dr. C. G. Cillié, professor of mathematics at the University of Stellenbosch; Dr. Bart J. Bok, associate director of Harvard Observatory; and Uco van Wijk, a graduate student also of Harvard.

During December, the ADH took a series of photographs of the sky on plates 10 inches in diameter, the field being practically five degrees. The photographs here and on the back cover were made within two weeks of the taking of the first star focus plate, yet they show detail in both stars and nebulosity hitherto unattainable for such large fields with any prior instruments in the Southern Hemisphere.

At the left above is a portion of the Large Magellanic Cloud, taken December 10-11, 1950, with a 90-minute exposure on Eastman 103aO emulsion; the seeing was poor. The reproduction is contact scale, 68 seconds of arc to one millimeter. Just above the center is the huge nebulosity variously known as 30 Doradus, the Tarantula or Loop nebula; were it only as far away as the Orion nebula it would give enough light to cast shadows on the earth at night. In the upper left of the picture is the main axis of the cloud. In the lower right is a strange planetary-like object, the exact nature of which requires further observations.

The lower picture shows a field of galaxies near the Fornax cluster. Dr. Bok used a 90-minute exposure on 103aO emulsion, on December 8-9, 1950. The reproduction, in order to bring out the many galaxies, is enlarged about 1½ times.

The back cover is also enlarged, about 1.6 times. It is a 60-minute exposure, on December 10-11, 1950, Eastman 103aO emulsion, with the seeing fair. It shows the region of the nebulosity associated with Eta Carinae, and should be compared with the back cover of the October, 1950, issue, and with the photographs in such books as **The Milky Way,** by Bok and Bok, where Figs. 4, 5, and 6 show this nebulosity photographed by three other Boyden station instruments.

AMERICAN ASTRONOMERS REPORT

Here are highlights of some papers presented at the 84th meeting of the American Astronomical Society at Haverford, Pa., in December. Complete abstracts will appear in the Astronomical Journal.

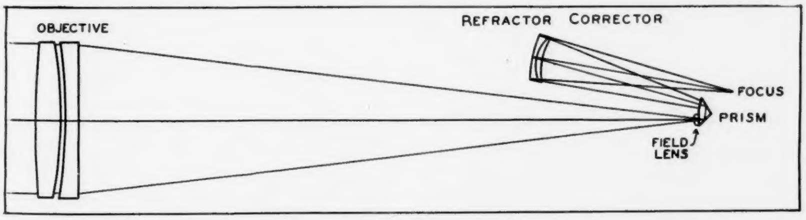
Apochromatic Correction for Refractors

Although large refracting telescopes perform almost ideally insofar as resolving power is concerned, their color curve or secondary spectrum has proved a handicap. Photographically, one must use prolonged exposure times to make up for the inefficiency of poorly focused colors in a star image. Spectrographically, a great percentage of light is lost at the slit jaws where poorly focused starlight fails to enter. Photoelectrically, it is difficult to exclude sky light sufficiently well or to work on close objects separately.

A form of telescope developed by Schupmann half a century ago is the basis for a system of auxiliary optics proposed by Dr. James G. Baker, of Harvard Observatory, which would make existing large refracting telescopes practically as color-free as reflectors. The proposed refractor corrector is a negative achromatic lens, the far surface of which is silvered or aluminized. It is situated beyond the focal plane of the telescope objective; a field lens is placed near the original focus. The concave mirror portion of the Mangin-type lens-mirror returns light to a real focus at unchanged scale, where the usual photoelectric and spectrographic attachments may be used. Different mechanical arrangements are possible, such as the one sketched here.

Dr. Baker's calculations show that the correction of secondary spectrum in the second focal plane is nearly complete, and at f/15 is within the Rayleigh limit over the spectral range from 4000 to 8500 angstroms. The diameter of the refractor corrector need not be more than one fifth that of the telescope's objective, but its ratio of diameter to focal length must be the same. The loss of light from the added optics is about 15 per cent, but this is insignificant compared to the advantages of bringing all wave lengths to a common focus.

Apochromatic astronomical lenses having three elements instead of two have been commercially available in the past, but their cost is high and their size relatively small. Amateur and professional astronomers alike can apply Dr. Baker's arrangement to refracting telescopes of any size.



A schematic representation of one way in which the optics proposed by Dr. Baker might be employed with a refractor. The refractor corrector is shown oversized for clarity; in practice it may be fitted inside the main telescope tube.

Color of Distant Galaxies

Several years ago Drs. Joel Stebbins and A. E. Whitford, of Washburn Observatory, startled the astronomical world with the discovery that very distant elliptical galaxies were about twice as red as they should appear were the expansion of the universe reddening the only effect on their colors caused by great distance.

One tentative explanation was that there was absorption of light in the space between galaxies, but the amount of matter required seems much too large to fit in with present models of the universe.

Another possibility, suggested by Dr. M. Schwarzschild, of Princeton University, was that we are really discovering the ancient history of the ellipticals. An object 230 million light-years away from us is seen by light that left it that long ago. Elliptical galaxies seem to differ from those of spiral structure in containing none of the dust and gas from which new red stars are formed. These stars rapidly use up their energy and perhaps evolve into some other type of object. Thus, Dr. Schwarzschild suggests that in the most distant ellipticals we see red stars that have since changed their character. In the nearby ellipticals no such red stars are seen. Therefore, the distant ellipticals appear redder than those nearby.

Now, Dr. Whitford and H. L. Johnson have employed a 1P21 photomultiplier attached to the 100-inch Mount Wilson reflector to extend the earlier observations. The colors and magnitudes of 10 elliptical galaxies in the Pegasus, Coma, and Bootes clusters have been obtained. The magnitudes range from 13.1 to 19.3, and the new data permit a color comparison between the four or five brightest galaxies in each cluster.

The former result of excessive reddening with distance is confirmed; the increase is roughly twice that predicted for the red shift from the expanding universe effect. Four-color measures of seven elliptical galaxies in nearby clusters show a mean energy curve very close to that of M32, the companion of the Andromeda nebula that has been used as a typical object in calculating the red-shift reddening. The most distant galaxies involved have velocities of recession of 39,000 kilometers per second.

The next step in the problem appears to be a similar investigation of distant spirals, for if they do not show the same excess reddening as the ellipticals then Dr. Schwarzschild's proposal would become the most tenable one.

The Colors of Meteors

The light of meteors, unlike that of stars, comes from various elements whose atoms are widely enough separated in gaseous form so that each atom can act individually and produce its characteristic hue. The combined effect of many atoms produces the observed light of the meteor. Sometimes one particular substance is very prominent in a meteor and is responsible for its marked color. For example, when magnesium is strong the meteor appears green. Sodium gives it a yellow color, and intense calcium produces a bright blue. In most cases, however, the resultant color is from a combination of different elements.

Five representative meteor spectra photographed at the Dominion Observatory from 1946 to 1950 have been measured by Dr. Peter M. Millman to determine the relative amounts of red and yellow light as compared with blue and violet. The ranges of wave lengths were, respectively, 5000-6700 and 3700-5000 angstroms. Vega was used as a standard star and all indices were corrected to the zenith. The meteors were two Giacobinids, two Perseids, and one sporadic, ranging in visual magnitude from zero to -5.

Dr. Millman finds from this preliminary study that the slower meteors (velocity 10 to 20 miles per second) are of about the same color as Vega. Meteors with velocities from 30 to 40 miles a second may be yellowish when they first appear, but as they brighten they rapidly become bluer and often end shining with

a deeper blue than any star in the sky. No bright meteors are really red or orange. Those reported as of such color have probably, in most cases, appeared low in the sky and have been reddened by the atmosphere just as is the setting sun.

This work is of value to observers planning extensive programs of meteor photography, for with a measure of the color to be expected in the case of an average meteor the right type of photographic emulsion can be selected.

Origin of the Zodiacal Light

A cloud of very small dust particles circling the sun in the plane of the earth's orbit scatters sunlight to produce the glow known as the zodiacal light. It appears after sunset and before sunrise as a wedge-shaped area extending along the ecliptic. These particles also scatter light about the sun at the time of a total solar eclipse and contribute to the luminosity of the corona.

Dr. Fred L. Whipple, of Harvard Observatory, has developed a theory to explain the origin of the zodiacal light particles as material blown off comets when their icy surfaces are vaporized by sunlight. The particles so expelled then spiral slowly into the sun under the retarding influence of the Poynting-Robertson effect. Dr. Whipple shows that the addition of only one ton of fine dust per second is sufficient to maintain the zodiacal light indefinitely, whereas according to his new theory of comets as composed of icy conglomerates they contribute on the whole some 30 tons per second.

Only a fraction of the cometary material can finally spiral into the sun because very few of the larger particles, of the pinhead or marble size that produce meteors, can avoid the attraction of Jupiter, which swallows them up before they have time to near the sun. Very small particles can spiral in more rapidly and evade the gravitational barrier set up by Jupiter.

Hence, there is now a quantitative theory relating Dr. Whipple's theory of comets, the rate of spiraling of small particles toward the sun, and the production and maintenance of the zodiacal light.

Members and guests of the American Astronomical Societ at the

Peculiar Shell Star

Beta-1 Monocerotis is one of numerous *B*-type stars whose spectra contain bright lines of hydrogen. They are generally pictured as rapidly rotating bodies: surface gravity at the equator of such a star is nearly balanced by centrifugal force. Consequently, gases stream out from the equatorial regions to form an extensive ring composed mostly of glowing hydrogen, which produces the bright lines. These appear widened by the Doppler effect of the rotation of the ring, and absorption by the outermost gases in the ring produces weak dark lines centrally placed in the bright ones. In a minority of the stars, the dark lines are very strong and sharp. These may be the few cases in which the gaseous ring is almost exactly edgewise toward the earth.

In a number of the bright-line stars, the two parts of the bright line that are separated by the dark line are variable in brightness. First the component of greater wave length (red) is stronger, then the one of shorter wave length (violet); the "period" of variation is usually a few years. Beta-1 Monocerotis is one of the stars whose bright lines change in this manner, which is called V/R variation. But among the brighter members of the class it is unique in being both a V/R variable and a shell star with a very long "period" of about 12.5 years.

Dr. Dean B. McLaughlin, of the University of Michigan Observatory, has sought to determine whether or not Beta-1 Monocerotis differs from the non-shell V/R variables that have weaker dark lines. In these other variables, the changes of brightness of the two components of emission are accompanied by correlated displacements of the bright lines and their central dark lines. Dr. McLaughlin's observations show that for Beta-1 Monocerotis also a bright line shifts in the same direction as its central dark line. The presence of appreciable emission, or its absence, makes no difference in the amount of shift of the dark line, except for a slight effect in the strongest measured bright line, Hβ, where a slight effect of photographic "crowding" may occur.

If it is supposed that the bodily shift of bright and dark lines is caused by motion in an orbit in a binary system, the V/R variations require that the gas between the two components of the double be glowing more brightly than that which lies on the outer side of the bright star. But against this hypothesis of binary motion, there is the lack of any indication of a spectrum of a second star and the changes have no precise periodicity. Beta-1 Monocerotis is probably not a binary, for it showed no variations at all from 1905 to 1918.

Dr. McLaughlin suggests that in this case there may take place large-scale expansion and contraction of a very extensive gaseous envelope about the star. The total dimensions of the envelope must be about the size of the orbit of Uranus, but the strong bright lines are probably produced within the inner part only, in a region no larger than the orbit of Mercury.

Socie at the 84th meeting, Haverford College, December 28, 1950.

80 per cent visibility should be detectable, and doubles of equal brightness as close as 0.05 second could be discovered and their co-ordinates measured.

Early-Type Stars in Cygnus

It is well known that the distribution of early-type stars along the Milky Way is not uniform. While some of this irregularity is a result of interstellar absorption, investigations such as that reported on by Dr. Nancy Roman, Yerkes Observatory, show that the space distribution of these hottest stars is highly non-uniform.

A region of 18 square degrees centered near the star P Cygni contains seven bright Wolf-Rayet stars and many *O* and early *B* stars. Slit spectra and photoelectric magnitudes and colors have been obtained for most of the early-type stars in this region, and these indicate that the distance of the aggregation is about 1,350 parsecs, or about 4,400 light-years. The Wolf-Rayet stars are similar to the normal *O*-type stars in absolute magnitude. The color excesses are so nearly the same for neighboring stars that this criterion alone could be used to decide if a star is a member of the aggregation.

The position of the well-known variable, P Cygni, near the center of so many early-type stars would make it likely that it is also at the same distance. Its absolute magnitude then would be −8, comparable with the brightest star in the Magellanic Clouds, S Doradus. The interstellar lines, and polarization measures, made by Adams and Hall, respectively, strengthen this probability.

The color of a normal star is a good indication of whether or not it is at the same distance as the other stars in a group. P Cygni has the same color as other *B*0 and *B*1 stars nearby. However, Dr. Roman pointed out that we do not know the color of P Cygni, and can say it is the color of a normal *B*1 star only if we are sure that it is a member of the aggregation.

Resolving Close Doubles

It is well known that an interferometer can be used to increase the resolving power of a telescope for double stars. It produces a number of fringes in a star image, and the distance between the center of a dark fringe and its neighboring bright fringe is called the resolving limit, since for doubles closer than this the bright fringes of one component can not be made to overlap completely the dark fringes of the other, thus causing uniformity and disappearance of the fringes. For the 18-inch refractor of the Flower Observatory, University of Pennsylvania, this limit is about 0.155 second of arc. This instrument is used for double-star work by Dr. Raymond H. Wilson, Jr., of Temple University, who described theoretical considerations to make possible detecting double stars with less separation than the resolving limit. Instead of the requirement that the fringes completely disappear when the interferometer slits are set at the position angle of a double star, he shows that this position angle can be determined and the separation estimated even when the fringes remain as much as 77 per cent visible.

In practice, the interferometer is rapidly oscillated until the position of minimum visibility of the fringes is found. Then the distance between the star components is estimated from the decrease in visibility at that position compared with their full visibility at an angle 90 degrees different, where the bright fringes of one star fall on the bright fringes of the other.

For two stars of zero separation, the visibility of the fringes would always be 100 per cent; for separation 0.052 second, it is 77 per cent; for 0.078 second, 50 per cent; and for the 18-inch resolving limit, 0.155 second, it can become zero. Dr. Wilson expects that under favorable conditions decrease to less than

On December 27th, demonstrations were given to AAS members of a new large experimental Spitz projector, as well as of an improved small type, shown in this picture. The dodecahedron carries small optical projectors for 1st-magnitude stars. In the picture are (left) Dr. Freeman D. Miller, University of Michigan Observatory, and Armand Spitz, inventor of the Spitz planetariums. Photo by Jules Schick.

BOOKS AND THE SKY

OUT OF MY LATER YEARS

Albert Einstein. Philosophical Library, New York, 1950. 282 pages. $4.75.

THIS IS a collection of 60 essays on a variety of subjects, written by Einstein between 1934 and 1950. On reading them, I felt that their author had stepped down from the gods (where popular legend has placed him) and become a human personality whom one could know and like.

At the close of the essay on Isaac Newton, astronomers may be pleased to find these words: "From observation of the stars have chiefly come the intellectual tools indispensable to the development of modern technique." This is flattering to us, so we are ready to believe it. The rest of the paragraph, however, brings us up short: "For the abuse of the latter [modern technique] in our time creative intellects like Newton's are as little responsible as the stars themselves, contemplating which their thoughts took wing. It is necessary to say this, because in our time esteem for intellectual values for their own sake is no longer so lively as it was in the centuries of the intellectual renascence."

Einstein not only holds that intellectual values are no longer rated what they used to be, but he also recognizes that, whether we admit it or not, the major events of life, both individual and corporate, are more apt to be decided by emotion than by reason. This recognition is simply that. There is no censure of others who use reason less than he. The nearest to emotional that Einstein becomes is in the section of the book called "My People." In one essay written in 1944, he states, "The Germans as an entire people are responsible for these mass murders and must be punished as a people . . . . we must not let ourselves be deceived again . . . ." But in a number of essays written since the war, dealing with the tasks ahead, he continuously appeals for more reason and understanding to be exerted in international affairs, and especially concerning atomic energy.

As a result of his attempt to face human problems with reason, he is in favor of socialism in the economic sphere and of a supranational government, stronger than the present United Nations, in the political sphere. His reasons for these views are spelled out plainly. Einstein is no starry-eyed idealist, and in his essays it is evident that he is as aware of difficulties which would arise under the new systems as he is of those which present themselves now.

Science is represented by only 30 per cent of the pages of the book, and by only 13 per cent of the separate titles. The material presented will teach no one the details of modern physics, yet it will give to many a "feel" for the subject, and an understanding of its broad principles. Relativity theory is found described both in prose and in mathematical language, and the treatments of this and of quantum mechanics are skillful.

Einstein's modesty shows up in a number of places. More than once he says he is embarrassed by the attention and love the world has shown him for doing what he could not help doing. He knows also that some hate him, but this does not hurt him. "I live in that solitude which is painful in youth, but delicious in the years of maturity."

One criticism is to be made of the book. Since so many of the essays contain allusions to specific current events, the reading would be facilitated if the date of the essay or address, and the name of the audience or publication were included in the body of the book. The dates are listed in the table of contents at the front, and the other information in a table of acknowledgments in the back. This requires considerable thumbing of the pages.

Out of My Later Years is to be recommended for the insight it affords into the mind of one of the greatest men of our century.

ROBERT FLEISCHER
Rensselaer Polytechnic Institute

WORLDS IN THE SKY

Carroll Lane Fenton and **Mildred Adams Fenton.** John Day Company, New York, 1950. 96 pages. $2.50.

MANY PEOPLE ask for a beginning book on astronomy, a book that will assume nothing and will give the reader an acquaintance with the universe we live in. **Worlds in the Sky** is such a popular book on astronomy, written for boys and girls of 12 and 13, but sufficiently elementary for nine-year-olds. It is, however, complete enough to interest the adult reader.

Following tradition, the book starts the reader with the earth on which we live, answering the questions of why we have night and day, and why the seasons change. It presents the sun as "our" star and the planets as the sun's big family. Comets, meteors, eclipses, and the moon are well described. Next, the authors take their readers through the tremendous distances to the stars. To children and also to most adults, distances that have to be expressed in light-years are almost incomprehensible. The Fentons,

in an excellent chapter, try to make these stellar distances meaningful by various comparisons and examples.

After describing giant and dwarf stars and novae, the book takes up galaxies, which it calls star-pinwheels. By trying to be graphic, the authors have in this case been inaccurate. To describe all extragalactic systems as star-pinwheels is like describing all types of fireworks as pinwheels.

The last chapter, "Pictures in the Sky," gives a good account of the constellations. The stories and drawings of the two favorites — the Big Bear and the Little Bear — are given, as well as directions for finding them and the North Star.

The book is attractively printed in clear type large enough for the younger reader. The many blue-and-white illustrations are by the authors. However, it is disappointing that the reproductions are so poor. When there are available so many beautiful photographs of the Andromeda nebula, which probably very closely resembles our own galaxy, it is regrettable that the authors used such a misleading drawing of our galaxy.

Mr. and Mrs. Fenton, who have written many science books for children, are not astronomers. This may be an advantage when it comes to making astronomy understandable to the layman, but it leads to inaccuracies. For instance, the astronomer is rather shocked when he reads of all the various phenomena in the sun, planets, and stars that are described as storms. To quote a few examples: "Sunspots really are terrible storms." Speaking of Jupiter, "Some of the red spots seem to be storms." Speaking of Cepheids, "Can you imagine what fierce storms must rage upon these big stars as they swell and contract?" It should be possible for a popular book to be written in everyday language and to be interesting, yet to retain scientific accuracy.

CECILE T. WEAVER
Mt. Hamilton, Calif.

PHOTOGRAPHY IN ASTRONOMY

E. W. H. Selwyn. Eastman Kodak Company, Rochester, N. Y., 1950. 112 pages. $2.75.

Photography in Astronomy describes itself as an "introduction to the practice of astronomical photography." The author is from the Kodak Research Laboratories in England. Much of the material in the book was collected during his recent stay in this country, in the course of which he visited several of the large observatories.

It is difficult to tell for what type of reader the "introduction" is intended— or useful. Specialized fields, of interest mainly to the professional astronomer, are briefly discussed from the point of view of the photographic problems involved. Copious use of the calculus and functional equations is made. But simple concepts, familiar to most amateurs, are elaborated upon, how to make a contact print, for instance, and the necessity for a polar-axis mounting. A book of 112 pages which attempts such a wide scope must suffer from incompleteness, and this one suffers from injudicious selection and emphasis.

Among the eight photographs of astronomical instruments we find the Yerkes 40-inch represented twice, once with the floor up and once with the floor down; the 200-inch telescope is barely mentioned. The nine or 10 reproductions of astronomical objects are all of excellent quality, but the brief descriptive captions are quite inadequate. In contrast to this the credit lines are long, and many include the code numbers of the Yerkes slide collection from which the reproductions were taken. There are a number of good diagrams, some of which are incompletely labeled, however.

Chapters III and IV summarize very well the properties of photographic materials and the fine structure of photographic images. Quite properly, the emphasis is placed on astronomical applications. Sensitometry, the failure of the reciprocity law, and the (Gurney-Mott) theory of latent image formation are discussed. Useful precepts for hypersensitizing plates are stated. The roles of turbidity, adjacency effects, and granularity are described.

The sixth and seventh chapters offer useful information on layout and work in a darkroom for the person who is unfamiliar with the rules for processing and reproduction. These two chapters may merit the book a place on the darkroom shelf.

In the second chapter there is a discussion of the limiting magnitudes of various instruments that may be of value to those who have not easy access to the original paper by Whipple and Rubenstein (mentioned in a footnote in the introduction).

As a reference book, **Photography in Astronomy** loses much of its value in not having an index. Further, it does not refer the reader to specific articles in the astronomical literature for fuller discussion of the subjects for which its own treatment is too brief.

The quality of binding and paper is excellent. The title is attractive, and the year 1950, the 100th anniversary of the first photograph of a star, would have been an appropriate time for the publication of such a book as this purports to be.

DONALD MacRAE
Warner and Swasey Observatory

NEW BOOKS RECEIVED

SOURCEBOOK ON ATOMIC ENERGY, *Samuel Glasstone*, 1950, *Van Nostrand*. 546 pages. $2.90.

This text, prepared under the direction of the technical information service of the Atomic Energy Commission, provides a comprehensive reference and textbook on the past, present, and possible future of atomic science.

SOME FAMOUS STARS, *W. M. Smart*, 1950, *Longman's Green*. 219 pages. $2.50.

As its name implies, this book discusses as individuals several well-known stars, together with the major problems in astronomy that they raise or help solve. Delta Cephei, Epsilon Aurigae, the companion of Sirius, and 61 Cygni are among the objects treated.

ATOMIC ENERGY AND THE HYDROGEN BOMB, *Gerald Wendt*, 1950, *McBride*. 192 pages. $2.75.

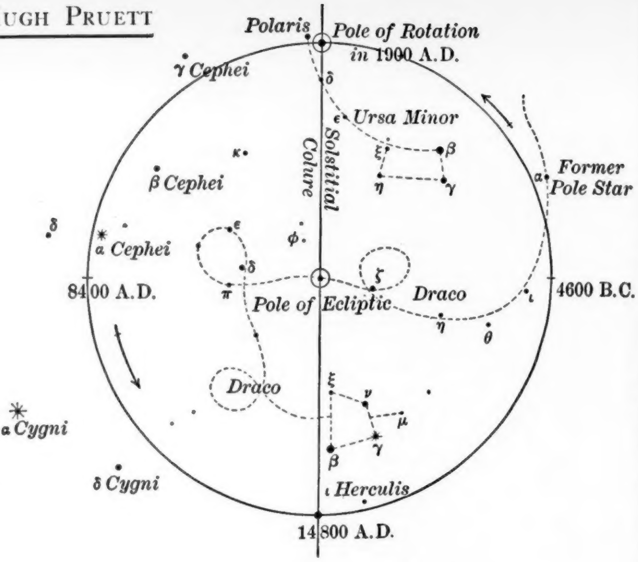
A book for people growing up in the atomic age, discussing the facts, principles, and future possibilities of atomic power.

TERMINOLOGY TALKS—J. Hugh Pruett

Sidereal Time (continued)

Dr. Samuel G. Barton calls attention to the distinction between true sidereal time and mean sidereal time, which he points out is explained in Smart's *Spherical Astronomy*, in the chapter on time. He writes further:

"Presumably mean time clocks are meant in the January discussion, as clocks do not carry apparent solar time. The local mean time differs from the local sidereal time by zero hours, that is, they agree, not at the time of the September equinox but about two days before, the difference resulting from the equation of time. Similarly, the times differ by 12 hours, not at the time of the March equinox, but about two days later. Some later statements in the January Talk require similar amendment."



This diagram shows the average motion of the celestial pole around the pole of the ecliptic. About 8000 A.D. Alpha Cephei will be the pole star, while Vega (not shown) will be near the pole by about 14,000 A.D. The diameter of the circle is about 47 degrees. Diagram from "Astronomy," by Russell, Dugan and Stewart.

Precession of the Equinoxes

The equinoxes are the two intersections (at angles of 23½ degrees) of the great circles on the sky, the ecliptic and the equator. The March (vernal) equinox is the intersection through which the sun, moving northward, passes about March 21st. Because of many perturbations (disturbances), principally those due to the attractions of the sun and moon on the earth's equatorial bulge, gyroscopic action causes the equinoxes to move westward among the stars at the present rate of about 50.3 seconds of arc annually. This movement is known as precession.

The Great Year

Since it is 360 degrees, or 1,296,000 seconds, around a circle, it is easy to calculate by dividing the latter figure by 50.2555 that at its present rate it will take the equinox 25,785 years to make a complete circuit of the ecliptic. This is the 25,800 years, sometimes rounded to 26,000, usually given in astronomy texts. This long expanse of time is often referred to as the Great Year. The daily motion in right ascension is close to 0.0084 second of time. This is the figure used last month in stating that the vernal equinox moves westward among the stars approximately 1/100 of a second of right ascension daily.

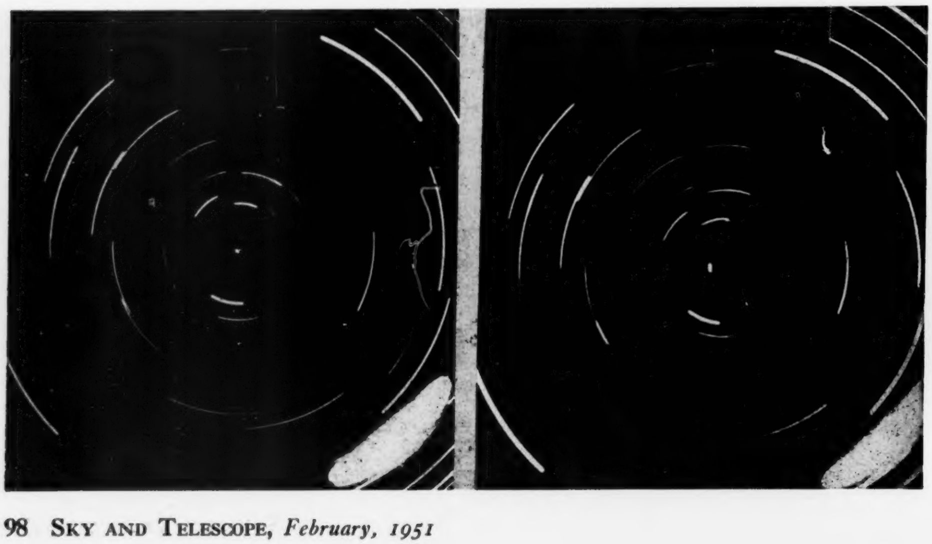
Precessional Confusion

The precession of the equinoxes mixes up astronomical computations considerably. It results in the constant changing by small amounts of the right ascensions and declinations of the stars. This is easily noted by inspecting the values for any star listed in the *American Ephemeris and Nautical Almanac* for the first and last days of any year. The epoch or time of celestial equatorial co-ordinates must be given where positions of celestial objects are specified.

As we have noted, precession also makes the sidereal day shorter than the "star" day, and causes the year of the seasons to be 20 minutes shorter than the time of the actual revolution of the earth around the sun. And finally it moves the signs of the zodiac so that they no longer correspond to the constellations from which they originally took their names.

Signs of the Zodiac

About 2,000 years ago, when the first real work was being done in mathematical astronomy, the March equinox was located in the western part of Aries. Thus came the name, the "first of Aries." The equinox has since backed up about 30 degrees westward and is now in the neighboring constellation. The sign of Aries, therefore, is now actually in Pisces. All the other signs of the zodiac are likewise located in the constellations to the west of those whose names they bear. This is rather confusing, yet some almanacs cling to the old usage. And the signs are also used in this way in that pseudo-science, astrology, whose fortune-telling advocates still falsely claim to receive the approval of the students of the noble science of astronomy.



In as short a period as 10 years, the motion of the earth's pole of rotation among the stars is noticeable. Compare these pictures made in 1925 (left) and 1935. The faint star that is almost exactly at the pole shows a short trail in the 1935 picture. Polaris is the very much overexposed trail in the lower right corner. Yerkes Observatory photographs.

GLEANINGS FOR ATM's

EDITED BY EARLE B. BROWN

Testing Your Telescope by Observations

IN THE COURSE of visiting many amateur astronomers and astronomical groups, the writer has frequently been asked for an opinion as to the worth of an amateur-made instrument. Occasionally, this has been in conjunction with exhibits at conventions and on other occasions.

A thorough test of any optical instrument requires the equivalent of an optical bench and auxiliary test equipment. As an alternate to or in the absence of such equipment, the writer has worked out, by trial and error, a series of tests that serve at least to rate assorted telescopes in a comparative way. If a comparison instrument is available so an independent rating can be assigned to the observing conditions, the test allows a very fair appraisal of the instrument under inspection; in the absence of such a standard telescope, the tests are still of considerable value.

Of course, it is realized that observing conditions vary widely at different places, and that seeing and transparency continually change at one place. This makes an absolute appraisal, from observing tests alone, impossible, which is why the standard comparison instrument mentioned above is necessary. The following conditions should be met:

1. The moon must be absent, or low in the sky, and either younger than the first or older than the last quarter. 2. The seeing must be at least 7 on a scale of 10, with 10 perfect; thus, fair steadiness of the telescopic image is required. 3. The transparency must be 3 to 4 on a scale of 5, with 5 perfect. This means not too much haze or smoke or glare from city lights.

If these conditions cannot be met, the tests may still be made, but some of them will be difficult or impossible.

Color and Spherical Correction. Observe Jupiter or Saturn, at about 100x, examining the image carefully for color effects and fringes. Observe detail on the planet's surface, noting the number of zones and belts visible, as well as spots, swirls, and other markings. In the case of Saturn, look for details in the rings, for Cassini's division, the shadow of the ball on the rings, and the shadows of the rings on the planet.

Many refractors fail in color correction, which will show up in this test. A lack of fine detail also indicates poor correction of the objective or eyepiece. A change in eyepiece will usually indicate where the blame should be placed. In a reflector, of course, any color effects must be in the ocular alone, since mirrors are inherently achromatic. Warning: Any telescope will show color fringes when the planet is low in the sky, as a result of refraction by the atmosphere; hence the test should be performed when the planet is near the meridian.

Field Size and Vignetting. Using a very low-power ocular, giving about 25x to 35x, with a field of over one degree, examine the clustering of stars in some rich star field. In the summer, the field east and west of Gamma Cygni is excellent. In the winter, the field near Iota Orionis, or the Double Cluster in Perseus, may be used. Note particularly the number of stars visible. Move the telescope so the stars near the center of the field move to the edge. Watch for any sign of dimming of the stars as they approach the edge. If such vignetting occurs in a reflector, the secondary mirror may be too small. Watch for distortion of the star images as they reach the edge of the field. The images should be small round circles throughout the field, without any sign of flare or coma, or of irregularity of shape.

Astigmatism. Center the telescope on Epsilon Lyrae, the well-known double double, using a power of about 100x. With an instrument of four inches aperture or larger, the two pairs of images should each split cleanly and without difficulty, and at the same focal point. An astigmatic mirror or lens will usually require a slightly different focus for each pair, and will not show both split simultaneously. Warning: Such a defect in figure may be caused by errors in either the primary or secondary reflections, but may also result from a "pinched" mirror (either primary or secondary), in which the mounting may be distorting a perfectly good mirror into an astigmatic shape. It is also sometimes, but not often, due to poor optical alignment of the mirrors, or to a poor eyepiece. Therefore, before condemning the mirror, try another eyepiece, and check the cells to make sure the mirrors are perfectly free.

Light-gathering Power. Unless magnitude charts are readily available, make use of the globular clusters. The great globular cluster in Hercules, M13, contains many stars of visual apparent magnitude about 13.4 or 13.5. A 6-inch telescope should readily reveal these stars on a good night, at about 100x, showing multitudes of individual stars. The stars in M3, in Canes Venatici, are about half a magnitude fainter, suitable for an 8-inch or a 10-inch instrument. M15, in Pegasus, is of about the same brightness, but more condensed; a 10-inch shows it very well at about 125x.

Resolving Power. This is, of course, the acid test of any telescope. For a 6-inch, during the summer months, Zeta Herculis is a good test. This is a double of one second of arc separation, the stars being of magnitudes 3.0 and 6.5. The difference in brightness makes this a very severe test, but not beyond a satisfactory instrument on a good night, at about 200x to 250x. In winter, Eta Orionis, magnitudes 4.0 and 5.0 at one second separation, is an equally good test, in part because of its more difficult southern position in the sky.

The ultimate test for a 6-inch, requiring an excellent instrument and exceptionally good seeing, is probably Gamma Coronae Borealis, 4.0 and 7.0 magnitude at 0".7 separation. It should be seen

double readily with a 10-inch. The ultimate for a 10-inch or 12-inch might be the blue star of the wide yellow-blue pair known as Gamma Andromedae. This is itself a close double. About 250x to 300x should resolve this blue star, provided both the seeing and the instrument are extremely good.

Dawes' rule that the resolving power in seconds of arc equals 4.56 divided by the diameter (in inches) of the primary mirror or lens may be taken as a working approximation, based on yellow stars of equal brightness. The resolving power of most instruments is better for blue stars than for yellow ones, and it is worse for red stars. In the case of Gamma Andromedae, note that the yellow star seems the larger of the two, even though it is single and the blue one is double.

While these tests are not definitive and do not separate, by themselves, imperfections in the objective from imperfections in the eyepieces used, they have proven to the writer more practical than the method using inside- and outside-focus images usually given in textbooks. Try the above tests on several good nights, and if you possess a really good instrument you will have the great satisfaction of having proved its worth by direct observations.

R. R. LaPELLE
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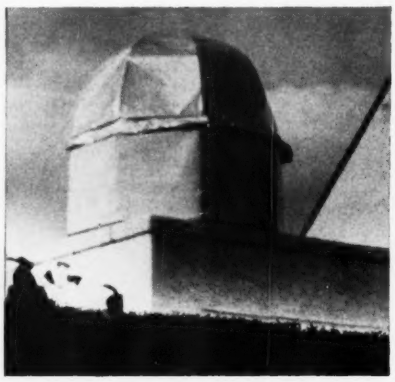
A ROOF-TOP OBSERVATORY

INSPIRED by an article in Gleanings in 1949, I decided to try my hand at constructing a small private observatory on my own roof. As can be seen from the photograph, the building is perched on a corner of the west wing of the house; it is securely clamped to the parapet by steel brackets. Originally, the inside diameter was to be nine feet, but shortage of lumber required reduction to six feet six inches and a total height of eight feet.

The observatory houses an 8½-inch reflector which, I must admit, seems a little too large for comfortable observing, but this lack of space is compensated for by a very warm and cosy atmosphere during the winter months.

The interior is electrically lighted, an extension cable being run out from a point inside the house. Double-flanged wheels running on a single brass rail support the dome, which can be swung around by hand as there is very little friction. I hope soon to install an electric drive that will propel both telescope and dome synchronously.



The observatory on the roof of J. G. Powell's home in Sussex, England.

After some experimenting, I decided to cover the dome with metallic fabric, consisting of plastic, tinfoil, and waterproof cloth laminated together, forming a very durable skin. Unfortunately, this is not so if the plastic, which is the outer layer, is not treated with either paint or cellulose, as the sun will quickly crack it, exposing the tinfoil. Aluminum paint is sprayed on to protect the plastic and to give a smart appearance to the observatory as a whole.

J. G. POWELL
"Broadwater," The Ridgeway
Felpham, Sussex, England

OBSERVER'S PAGE

Universal time is used unless otherwise noted.

Visual Observing Programs for Amateurs — XI

Variable Star Observing — (continued)

LAST MONTH we discussed locating a variable star, and the difficulties that scale and appearance of the field might give us.

We are troubled too by the orientation of objects in the sky. Should we hold our charts upright as they are printed, that is, with south on the chart towards the zenith, or at some other angle? In the case of refractors, hold the chart in such a position that south points toward Polaris. When you are using binoculars, north should be pointed toward Polaris.

With reflectors the situation is more complicated. If you have a Newtonian, on an equatorial-type mounting, with the polar axis pointing roughly toward Polaris, and if the eyepiece points in toward the polar axis, and the eyepiece's optical axis is parallel to the declination axis, then the orientation is as follows: When looking into the eyepiece, hold the chart up against the telescope tube with its north and south line at right angles to the tube, and the south end of the chart toward the north side of the tube; what you observe in the eyepiece will then appear at the same angle as what you see on the chart. If, however, the reflector is not mounted equatorially, or if the polar axis does not point fairly close to the north pole, or if the tube is rotated so that the eyepiece's optical axis is not parallel to the declination axis, then the field may assume almost any angle in the eyepiece and the observer will have to figure things out for himself by trial and error on the stars.

When you use a Springfield-mounted telescope, the field may assume almost any angle. Cassegrainian telescopes have the same orientation of the field of view as refractors. Modified Cassegrainians have a reversed field of view.

In searching for variable stars, other difficulties may arise to plague us. Some variable stars are widely separated from any bright neighbors, so that you may have to follow a trail of 10th- or 11th-magnitude stars to reach them. This will have to be done with the main instrument using a power of around 20 or 30. If the moon is bright, or if there is a light haze in the sky, you may have trouble in locating the naked-eye stars within five or 10 degrees of the variable star. Under such circumstances, confine your efforts to fairly bright stars which you already know well how to locate. Sometimes you may hunt for a variable star and almost find it, only to discover that it has just set behind a nearby house.

Once I found a fairly bright star which was not marked on my chart in the field of 201437b WX Cygni (the "b" merely means that there is another variable star so nearby that it has the same designation number 201437). This made the identification difficult and I thought at first that I had found a faint nova. Later I learned that the interloper was a little-known variable star which was temporarily bright. In 1945 I saw a 6th-magnitude star which should not have been in the field of 042215 W Tauri, and two years later I had a similar experience in the field of 074922 U Geminorum. Two hours of intermittent careful watching with a 75x eyepiece showed some motion in each case, indicating that these objects were asteroids.

The above general method of locating a variable star presupposes sufficient familiarity with the constellations so that one can, with the aid of an atlas and flashlight, identify with certainty such relatively unfamiliar objects as, for example, Triangulum, Alpha Piscium, Alpha Ceti, Gamma Geminorum, 18 Leonis, Gamma Coronae Borealis, Nu Ophiuchi, Zeta Scuti, Sagitta, Delphinus, and ω^1 and ω^2 Aquarii.

If you cannot find a variable star easily on any particular night, let it go and try some other night. One's mind may have developed a quirk that night. Maybe the star is unfavorably placed, near the zenith or partly obscured by haze if near the horizon. Intermittent clouds may be making the region seem unfamiliar. Perhaps the variable star itself may be so bright or faint as to make an area seem totally unfamiliar. Some stars are troublesome to some people. I have had friends tell me that they could not locate 200938 RS Cygni because the Milky Way is so full of stars thereabouts. I do not have trouble with RS Cygni and can always locate it in 15 seconds. However 194632 Chi Cygni, which I have seen scores of times, occasionally eludes me entirely, especially after it has passed from east of the meridian to west of it, so that the field seems reversed.

DAVID W. ROSEBRUGH
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SATURN'S SATELLITES

Times of configurations of Saturn's satellites are given below for February and March in the same manner that they were presented last month. Refer to the January issue, page 74, for an explanation of the data, and a table giving the periods, magnitudes, and distances of the satellites.

Mimas. February: 6, 20.1; 14, 9.0; 21, 21.9. March: 1, 10.8; 8, 23.7; 16, 12.6; 24, 1.6; 31, 14.5. April: 8, 3.4.

Enceladus. February: 2, 11.9; 13, 10.9; 24, 9.9. March: 7, 9.0; 18, 8.0; 29, 7.0. April: 9, 6.0.

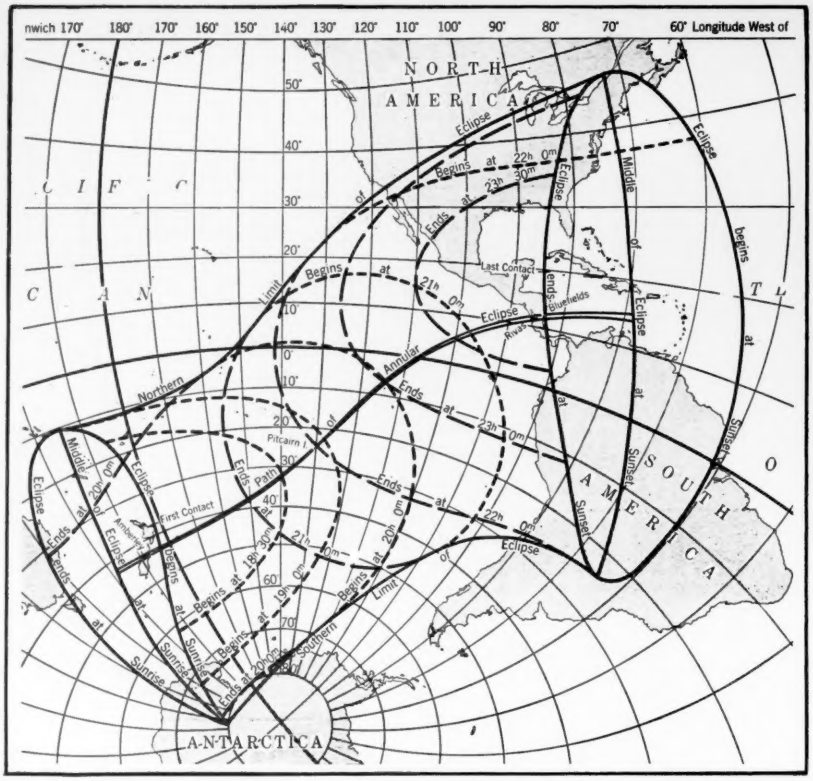
Tethys. February: 14, 8.4. March: 1, 10.7; 16, 13.1; 31, 15.4. April: 15, 17.7.

Dione. February: 3, 10.6; 14, 9.3; 25, 7.9. March: 8, 6.5; 19, 5.1; 30, 3.7. April: 10, 2.3.

Rhea. February: 6, 11.5; 24, 13.0. March: 14, 14.2. April: 1, 15.6.

Titan. February: **I**, 2, 13.3; **W**, 6, 13.5; **S**, 10, 18.0; **E**, 14, 16.7; **I**, 18, 11.3; **W**, 22, 11.3; **S**, 26, 15.7. March: **E**, 2, 14.4; **I**, 6, 9.0; **W**, 10, 8.9; **S**, 14, 13.2; **E**, 18, 12.0; **I**, 22, 6.5; **W**, 26, 6.3; **S**, 30, 10.7. April: **E**, 3, 9.6; **I**, 7, 4.1.

Iapetus. February: **S**, 10, 3.0. March: **E**, 2, 10.5; **I**, 21, 7.3. April: **W**, 9, 1.5.



In this diagram of the March 7th eclipse, taken from the "American Ephemeris and Nautical Almanac," Universal time is used.

THE SOLAR ECLIPSE OF MARCH 7th

THE FIRST of two solar eclipses in 1951, both of the annular type, occurs on March 7th, the second on September 1st. Both will be visible in partial phases from regions of the United States, generally at or near sunset on March 7th, and at sunrise on September 1st, and the annular phase of the September eclipse will be observable, as will be described later this year.

The path of the March annular phase is shown on the chart; maximum duration of the annulus occurs at the end of the path south of Haiti, and amounts to one minute, 38 seconds. The moon will have an apparent diameter only 51″ less than that of the sun, so observers on the central line will see an extremely narrow ring around the silhouette of the moon.

The greatest partial eclipse in the United States will be viewed from Florida, with 44 per cent of the sun's diameter being obscured by the moon at Tallahassee. The time of mid-eclipse is within a few minutes of 22:40 UT for most of the following stations, corresponding to 5:40 p.m. Eastern standard time:

Atlanta, Ga., and Austin, Tex., 34%; Buffalo, N. Y., 9%; Cincinnati, Ohio, 17%; Cleveland, Ohio, 12%; Flagstaff, Ariz., 3%; Kansas City, Mo., 10%; Madison, Wis., 3%; New Orleans, La., 41%; New York, N. Y., 17%; St. Louis, Mo., 16%; Washington, D. C., 22%.

The sun sets at about 6 o'clock at Philadelphia, where the magnitude of the eclipse is 19 per cent. At Cambridge, Mass., maximum observed obscuration of 13 per cent occurs at sunset.

Watch for first and last contacts and the progress of the moon over the sun's disk, protecting your eyes with very heavily smoked glass or dense film negative. First contact will generally be close to the southern limb of the sun, and from the East Coast the sun will set while the eclipse is in progress. Near sunset will be an excellent time for photographs because of the dimming of the sun's light and the inclusion of the horizon in the picture for additional interest. Color photographs may be attempted, especially if clouds are nearby.

If a telescope is used to observe the eclipse, avoid damage to your eyes by projecting the image through an eyepiece onto a white cardboard, or use proper solar eyepieces and filters if they are available.

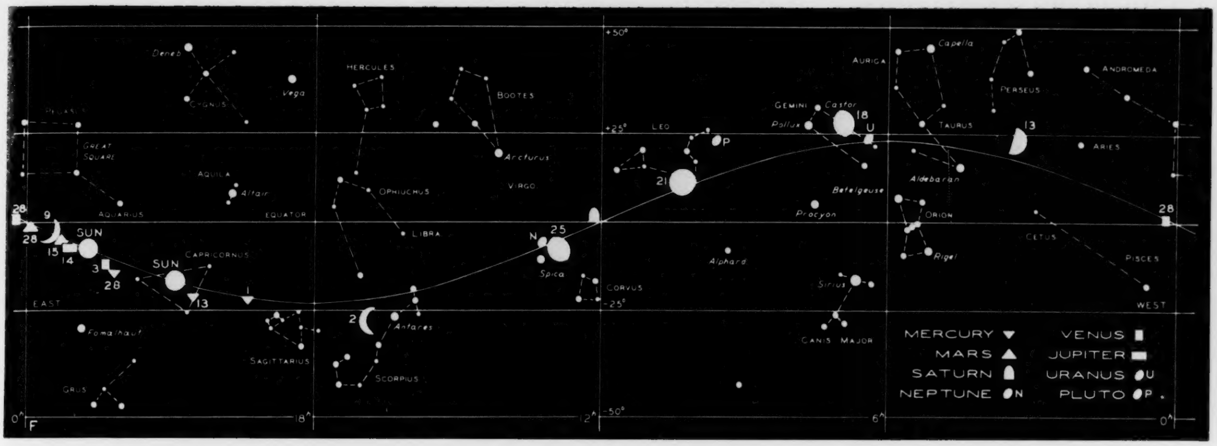
EDWARD ORAVEC

COMET MINKOWSKI

Continuing the ephemeris of Comet Minkowski, 1950b, which appeared on page 34 of the December issue, the following are positions for February through early May for this object, predicted to be of the 9th magnitude, for 0^h UT:

Feb. 3, 14^h $37^m.4$, −27° 38′; 13, 14^h $19^m.2$, −29° 47′; 23, 13^h $53^m.1$, −31° 48′; Mar. 5, 13^h $18^m.1$, −33° 16′; 15, 12^h $34^m.9$, −33° 38′; 25, 11^h $48^m.3$, −32° 27′; Apr. 4, 11^h $04^m.7$, −29° 49′; 14, 10^h $28^m.8$, −26° 24′; 24, 10^h $01^m.9$, −22° 55′; May 4, 9^h $43^m.0$, −19° 50′.

The nearest approach of Comet Minkowski to the earth, at a distance of 1¾ A.U., is predicted for late March.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown.

PHASES OF THE MOON

New moon	February 6,	7:54
First quarter	February 13,	20:55
Full moon	February 21,	21:12
Last quarter	February 28,	22:59
New moon	March 7,	20:50

	February	Distance	Diameter
Perigee	3, 15^h	226,700 mi.	32′ 45″
Apogee	15, 10^h	251,400 mi.	29′ 32″
	March		
Perigee	2, 7^h	229,800 mi.	32′ 19″

Mercury, close to the sun all month, may be glimpsed the first few days of February rising an hour before the sun; the planet will then be of zero magnitude.

Venus moves out of the evening twilight zone in early February, setting two hours after the sun at the end of the month. There will be interesting conjunctions of Venus, Mars, and Jupiter. On February 7-8 an occultation of this brightest planet occurs; see page 76 of the January issue for further information.

Mars, setting as evening twilight ends, will be exceedingly difficult to locate without optical aid. On February 7th, Mars and Jupiter will be in close conjunction, and on the 16th Mars will be 35′ north of Venus at 4:00 UT.

Jupiter will vanish from view in the western sky during February. It is in conjunction with Venus on the 11th, Jupiter 26′ north.

Saturn is visible most of the night as it nears opposition next month. It is of magnitude +0.9, and is located in western Virgo. The rings are closing once more, their inclination to the line of sight less than four degrees on the 15th.

Uranus can be located easily in opera glasses, for it is on the meridian at 9:45 p.m. on the 15th of February. Look 1° northeast of Mu Geminorum for a 6th-magnitude star. Several nights of observation will reveal the planet's motion, along the path shown in the accompanying chart.

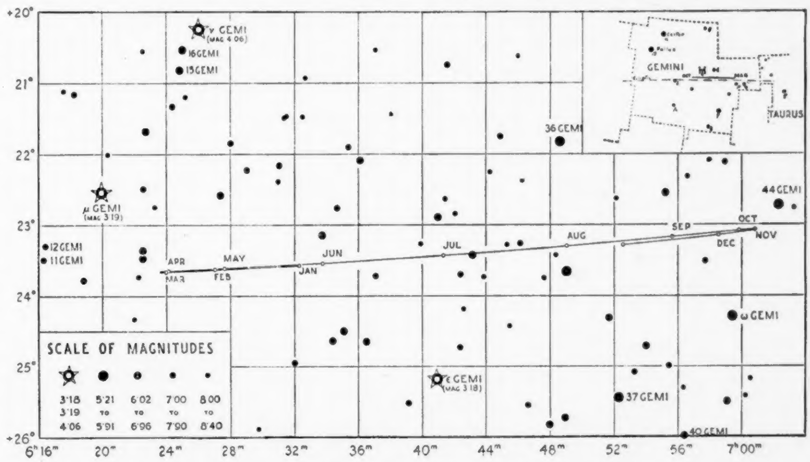
Neptune, visible in binoculars, is about 1½° southeast of Theta Virginis, as shown on the accompanying chart.

Pluto is in opposition to the sun on February 8th, at a distance of about 3,260 million miles from the earth. The faintness of the planet, 15th magnitude, requires a telescope of 12-inch aperture or more and a chart or photograph of the region to the 16th magnitude for positive identification. Pluto is now in Leo, located about 1¾° west and ½° south of Epsilon. Its position at opposition is 9^h 36^m 2^s, +23° 32′.3 (1950 co-ordinates).

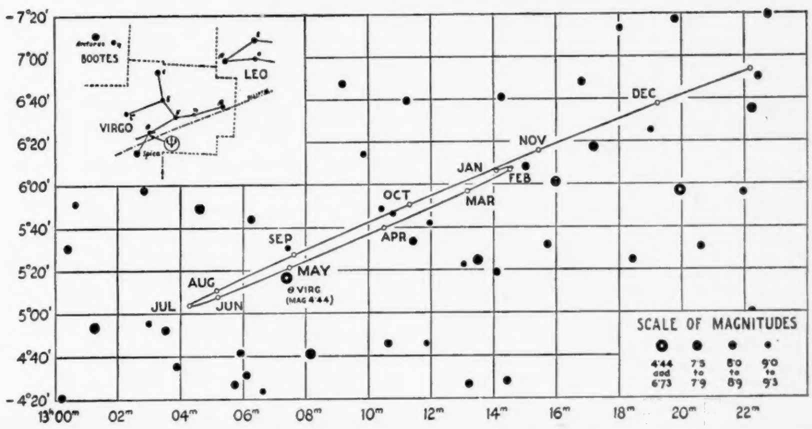
E. O.

UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, and the result is your standard time on the day preceding the Greenwich date shown.



The path of Uranus among the stars in Gemini during 1951 is shown above; that for Neptune among the stars in Virgo, below. In each case the field is inverted, with south at the top, as seen in an astronomical inverting telescope. The scale of the charts is not the same. From the 1951 "Handbook" of the British Astronomical Association.



DEEP-SKY WONDERS

SOME easy steps taken during the winter months will make both you and your telescope better fitted to brave the zero blasts. Don't shirk on clothing for yourself; it requires an unbelievable amount if you expect to stay out in low temperatures for three or four hours.

For the telescope, cloth caps—your wife can make or knit them — that fit over the metal ends of the oculars will make observing much more comfortable and may even save you a touch of frostbite. A drop of thin oil or some graphite may smooth out the bearings on your equatorial mounting. But this writer has seen several mountings which, because of the contraction of the brass parts, actually froze tight. Mechanical clock drives are often subject to this — little can be done except to rebuild the drive. You can test a drive for low temperatures by putting it in a good deep freeze at 20° below zero.

This month, near the galactic plane in Monoceros, Orion, and Gemini, the sweeper of the skies can find many clusters of Herschel's class VIII—coarse, scattered clusters. Many are not included in modern catalogues of galactic objects, but they are always interesting to the owner of a small telescope and are better yet in a rich-field.

Try 40[8], NGC 2331; 11[8], NGC 2395; 9[8], NGC 2234; 26[8], NGC 2129; 24[8], NGC 2169; and 3[8], NGC 2251. All and more are plotted in Norton's **Star Atlas** by their Herschel numbers. These clusters look well in small instruments with low powers. The exact appearance of a nebula or cluster in a telescope depends on so many factors that it is difficult to give an appropriate description. The magnification, f/ratio, resolving power of the optical system, and the various physiological and psychological characteristics of the human eye itself need all to be considered.

WALTER SCOTT HOUSTON

VARIABLE STAR MAXIMA

February 2, R Normae, 7.2, 1528**49**; 10, RR Scorpii, 6.0, 1650**30**a; 12, S Herculis, 7.6, 164715; 22, R Ophiuchi, 7.6, 1702**15**. March 2, U Orionis, 6.6, 054920a; 2, R Geminorum, 7.1, 070122a.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the predicted magnitude, and the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern).

OCCULTATION PREDICTIONS

February 7-8 **Venus** −3.3, 22:44 −9-36, 2, Im: **A** 23:13.4 ... ... 129; **B** 23:00.4 −1.0 −2.7 106; **D** 22:58.8 −1.3 −2.8 107; **E** 22:49.3 −2.0 −2.3 102; **G** 22:15.5 −0.8 +0.8 32; **H** 21:52.7 −1.8 +1.2 50; **I** 22:07.1 −0.6 +1.4 20. Em: **D** 23:40.7 +0.3 +2.1 184; **E** 23:36.1 +0.3 +2.4 183; **G** 23:29.2 −1.2 −0.6 251; **H** 23:19.6 −1.2 +1.0 222; **I** 23:16.8 −1.7 −0.6 262.

February 13-14 **q Tauri** 4.4, 3:42.3 +24-18.9, 8, Im: **G** 6:55.6 −0.5 −1.0 68; **I** 6:52.1 −0.6 −1.3 80.

February 13-14 **20 Tauri** 4.0, 3:42.9 +24-13.0, 8, Im: **G** 7:11.9 −0.1 −1.8 96; **I** 7:13.0 −0.2 −2.2 108.

February 27-28 **Pi Scorpii** 3.0, 15:55.9 −25-58.5, 22, Im: **F** 9:01.6 −2.1 +1.7 71. Em: **F** 9:52.6 −0.1 −1.6 342.

For standard stations in the United States and Canada, for stars of magnitude 5.0 or brighter, data from the **American Ephemeris** and the **British Nautical Almanac** are given here, as follows: evening-morning date, star name, magnitude, right ascension in hours and minutes, declination in degrees and minutes, moon's age in days, immersion or emersion; standard station designation, UT, **a** and **b** quantities in minutes, position angle on the moon's limb; the same data for each standard station westward.

The **a** and **b** quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computations of fairly accurate times for one's local station (long. **Lo**, lat. **L**) within 200 or 300 miles of a standard station (long. **LoS**, lat. **LS**). Multiply **a** by the difference in longitude (**Lo — LoS**), and multiply **b** by the difference in latitude (**L — LS**), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted time to obtain time at the local station. Then convert the Universal time to your standard time.

Longitudes and latitudes of standard stations are:

A +72°.5, +42°.5	**E** +91°.0, +40°.0
B +73°.6, +45°.6	**F** +98°.0, +31°.0
C +77°.1, +38°.9	**G** +114°.0, +50°.9
D +79°.4, +43°.7	**H** +120°.0, +36°.0
I +123°.1, +49°.5	

Planetarium Notes

BALTIMORE: *Davis Planetarium.* Maryland Academy of Sciences, Enoch Pratt Library Building, 400 Cathedral St., Baltimore 1, Md., Mulberry 2370.

SCHEDULE: 4 p.m. Monday, Wednesday, and Friday; Thursday evening, 7:45, 8:30, 9:30 p.m. Admission free. Spitz projector. Director, Paul S. Watson.

BOSTON: *Little Planetarium.* Boston Museum of Science, Science Park, Boston 14, Mass. Richmond 2-1410.

SCHEDULE: Tuesday thru Friday at 3:30 p.m.; Saturday, 2:00 and 3:30 p.m.; Sunday, 3 and 4 p.m. Spitz projector. In charge, Charles A. Federer, Jr.

BUFFALO: *Buffalo Museum of Science Planetarium.* Humboldt Parkway, Buffalo, N. Y., GR-4100.

SCHEDULE: Sundays, 2:00 to 5:30 p.m. Admission free. Spitz projector. For special lectures address Elsworth Jaeger, director of education.

CHAPEL HILL: *Morehead Planetarium.* University of North Carolina, Chapel Hill, N.C.

SCHEDULE: Daily at 8:30 p.m.; Saturday and Sunday at 3:00 p.m. Zeiss projector. Director, Roy K. Marshall.

CHICAGO: *Adler Planetarium.* 900 E. Achsah Bond Drive, Chicago 5, Ill., Wabash 1428.

SCHEDULE: Mondays through Saturdays, 11 a.m. and 3 p.m.; Sundays, 2:30 and 3:30 p.m. Zeiss projector. Director, Wagner Schlesinger.

KANSAS CITY: *Kansas City Museum Planetarium.* 3218 Gladstone Blvd., Kansas City 1, Mo., Chestnut 2215.

SCHEDULE: Wednesday and Saturday, 3:30 p.m.; Sunday, 3:00 and 5:00 p.m. Spitz projector. Director, Charles G. Wilder.

LOS ANGELES: *Griffith Observatory and Planetarium.* Griffith Park, P. O. Box 9787, Los Feliz Station, Los Angeles 27, Calif., Olympia 1191.

SCHEDULE: Wednesday and Thursday at 8:30 p.m.; Friday, Saturday, and Sunday at 3 and 8:30 p.m.; extra show on Sunday at 4:15 p.m. Zeiss projector. Director, Dinsmore Alter.

NEW YORK CITY: *Hayden Planetarium.* 81st St. and Central Park West, New York 24, N. Y., Endicott 2-8500.

SCHEDULE: Mondays through Fridays, 2, 3:30, and 8:30 p.m.; Saturdays, 11 a.m., 2, 3, 4, 5, and 8:30 p.m.; Sundays and holidays, 2, 3, 4, 5, and 8:30 p.m.; Wednesdays and Fridays, 11 a.m., for school groups. Zeiss projector. Chairman, Robert R. Coles.

PHILADELPHIA: *Fels Planetarium.* Franklin Institute, 20th St. at Benjamin Franklin Parkway, Philadelphia 3, Pa., Locust 4-3600.

SCHEDULE: Tuesdays through Sundays, 3 p.m.; Saturdays, 11 a.m.; Saturdays, Sundays, and holidays, 2 p.m.; Wednesdays, Fridays, and Saturdays, 8:30 p.m. Zeiss projector. Director, I. M. Levitt.

PITTSBURGH: *Buhl Planetarium and Institute of Popular Science.* Federal and West Ohio Sts., Pittsburgh 12, Pa., Fairfax 4300.

SCHEDULE: Mondays through Saturdays, 2:15 and 8:30 p.m.; Sundays and holidays, 2:15, 3:15 and 8:30 p.m. Zeiss projector. Director, Arthur L. Draper.

PORTLAND, ORE.: *Oregon Museum of Science and Industry Planetarium.* 908 N.E. Hassalo St., Portland 12, Ore., East 3807.

SCHEDULE: Saturday, Sunday, and Wednesday, 4:00 p.m.; Tuesday, Thursday, and Friday, 8:00 p.m.; Saturday show for children only, 10:30 a.m. Spitz projector. Director, Stanley H. Shirk.

SPRINGFIELD, MASS.: *Seymour Planetarium.* Museum of Natural History, Springfield 5, Mass.

SCHEDULE: Tuesdays, Thursdays, and Saturdays at 3 p.m.; Tuesday evenings at 8 p.m.; special star stories for children on Saturdays at 2 p.m. Admission free. Korkosz projector. Director, Frank D. Korkosz.

STAMFORD: *Stamford Museum Planetarium.* Courtland Park, Stamford, Conn.

SCHEDULE: Sunday, 4:15 p.m. Special showings on request. Admission free. Spitz projector. Director, Robert E. Cox.

SKY-GAZERS EXCHANGE

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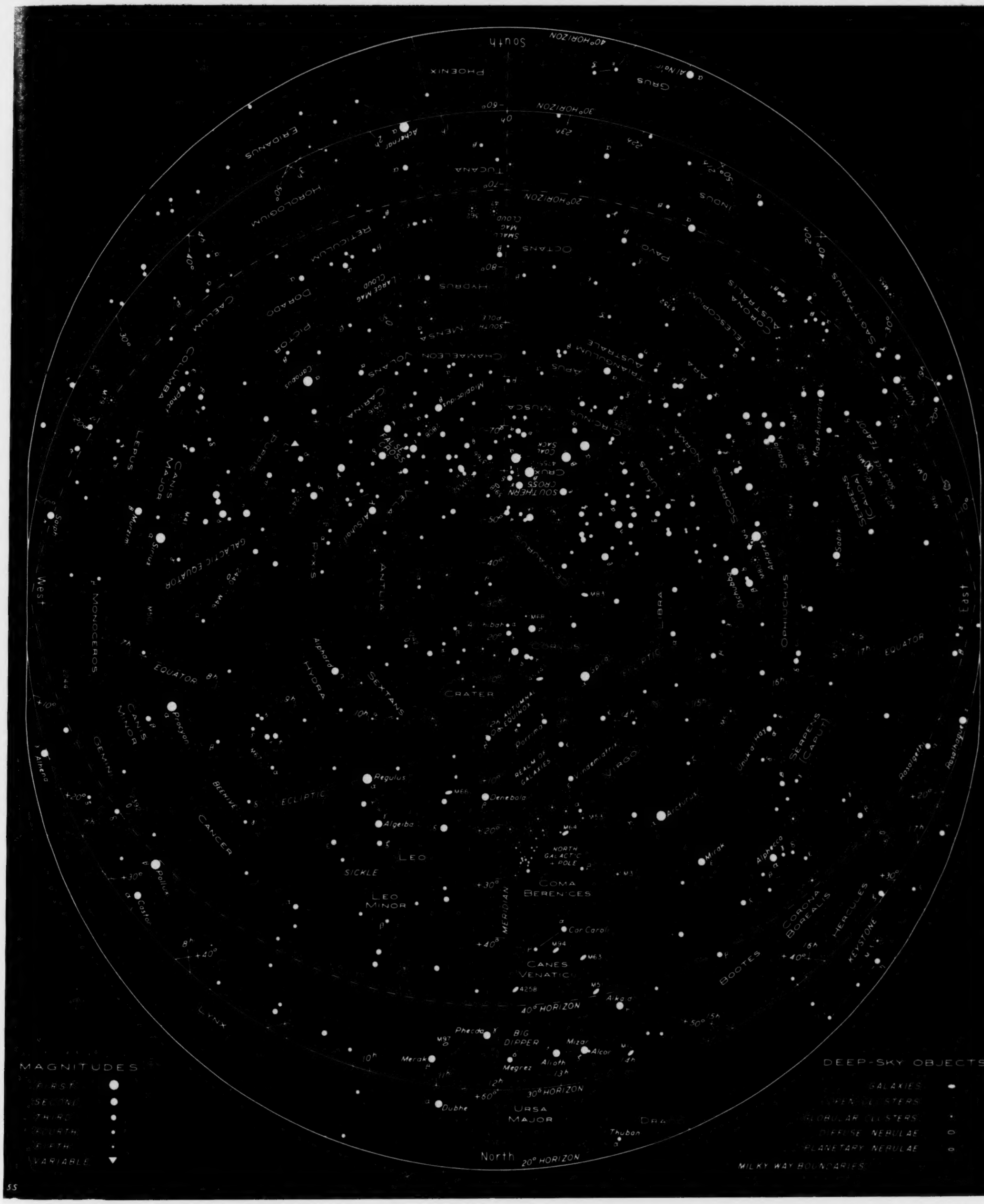
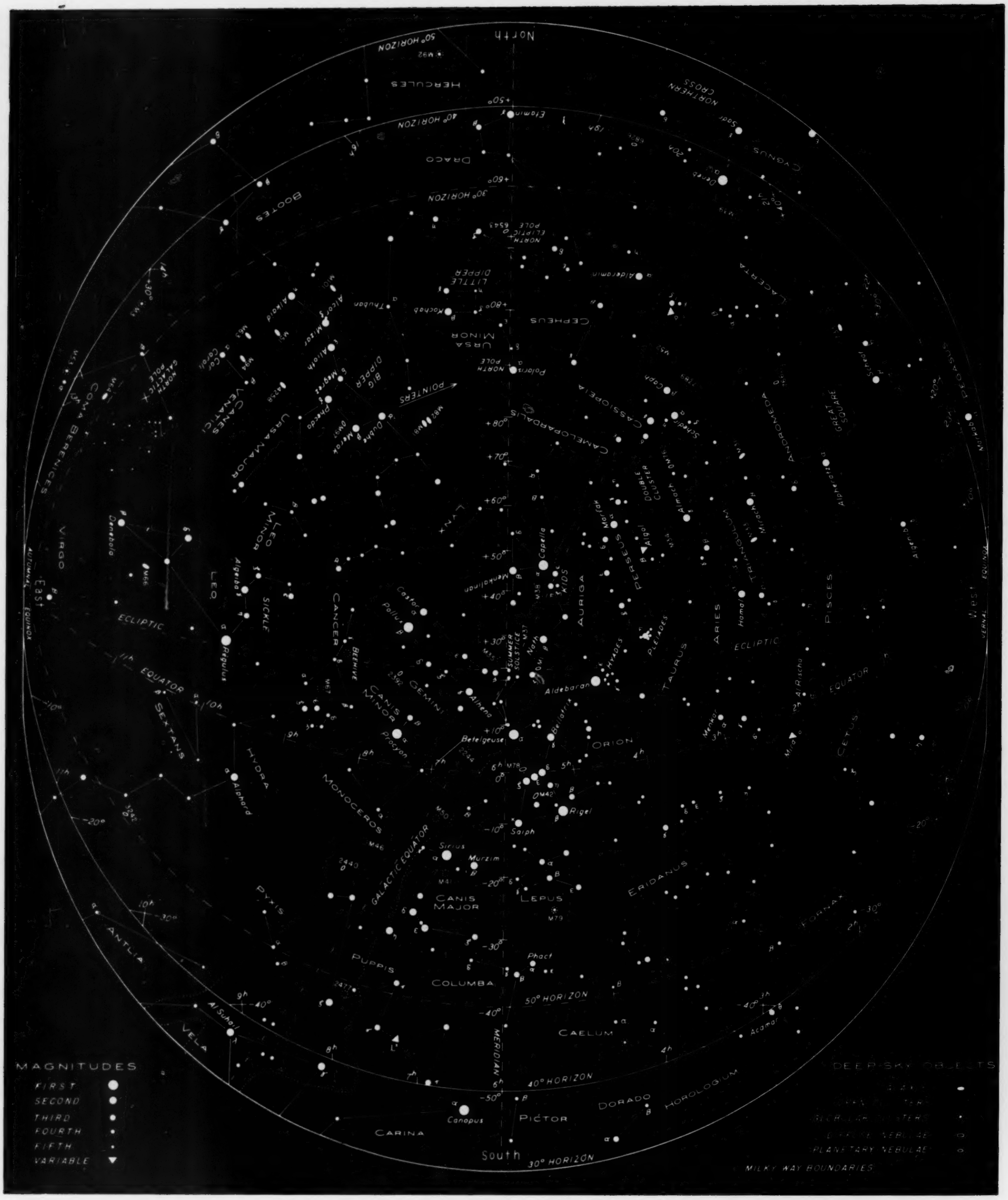


The sky as seen from latitudes 20° to 40° south, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of May, respectively.

SOUTHERN STARS

ALTHOUGH the splendor of the Milky Way toward the south dominates the sky of Southern Hemisphere observers at the time of this chart, many interesting configurations of stars are to be seen in the northern half of the sky, including the "diamond of Virgo." Like the Vega-Deneb-Altair combination, this four-sided figure extends across several constellations. Spica in Virgo and Arcturus in Bootes form the brighter side of the diamond; they are preceded by Denebola in Leo and Cor Caroli in Canes Venatici. Within the diamond lies the north galactic pole and a host of galaxies.

With the naked eye, the Coma Berenices cluster attracts attention. Its brightest star is only of the 4th magnitude; the shimmering mass of light can be resolved into stars by careful observation. The cluster is steeped in legend; mythology attributes these celestial locks to Berenice, wife of Ptolemy Soter of Egypt. To fulfill her vow to gain her husband's safe return from war with the Assyrians, Berenice had entrusted her long tresses to the temple of Aphrodite, from which they were stolen. But the priests consoled the royal family by pointing out this hitherto unnamed constellation (previously the tuft in the Lion's tail). O. G.



The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of February, respectively.

STARS FOR FEBRUARY

THE CANINE companions of Orion climb toward the meridian on February evenings. Procyon and Sirius in the triangle with Betelgeuse are well known, but how many of us can name the other stars in Canis Major and Canis Minor? Beta in the Smaller Dog is Gomeisa, which with Procyon makes a pair somewhat like that of Castor and Pollux about 20 degrees to the north. It has also been called Al Murzim, according to Allen, which is the name of Beta Canis Majoris. In each case the Beta star "announces" the rising of the brilliant star in the constellation.

Murzim is in the forefoot of the Larger Dog. Following Sirius is a 4th-magnitude star, Muliphen, in the dog's head, a name that Allen says Burritt improperly borrowed from Delta Canis Majoris and stars in Columba. In the dog's back is Wesen (Delta), and making a triangle with it are Adhara (Epsilon) and Aludra (Eta). To the west of these bright stars is the fainter Furud (Zeta).

Between the dogs lies a mediocre group of unnamed stars, Monoceros, the Unicorn, a modern constellation. It contains over 60 naked-eye stars, perhaps more than 100, depending on your eyesight and which authority you prefer. O G.

G